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AN AMERICAN ENGINEER IN CHINA.*

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LAST spring, when The Franklin Institute extended to me its very complimentary invitation to deliver a lecture to the title of "An American Engineer in China," it appeared as if industrial development in that country would continue to progress or remain stationary, just as it had been doing for some years in the past, regulated largely by the intrigue of European politics, and in which the American engineer was destined to play but a small part. At that time the possibility of a war which would embroil all of the European powers which had interests in China was scarcely within the realm of probability. Although at this time it is not possible to set limits to the effects that will follow this war, nevertheless there can be no doubt but that the effects will be so far reaching as to include China and Chinese enterprises, and it is not impossible that the position of an American engineer in China may be greatly altered, and, if so, it can be altered only to his benefit. The moment seems, therefore, opportune to briefly review the present condition of China's engineering development, including a review of her mineral wealth, and recall the factors that have influenced such development. The great world-change that is bound to come will surely cause the future development to follow new lines, under a greatly-altered combination of in-

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fluences and with results that no man can now foresee. All that we know is that we are at the point of departure for a new course whose bearings are now undetermined.

Whenever China or things Chinese are considered there is always a great opportunity for a diversity of views, leading at times to direct contradictions between even accurate observers, owing to difference in viewpoint. Chinese character and Chinese customs are always open to misunderstanding, due, perhaps, to the fact that they are so frequently just the opposite from what we do or would do under like conditions, and to the further fact that the several parts of the country differ radically between themselves in local customs, architecture, and mode of living, and perhaps largely to the lack of intercommunication in spoken speech. Thus we frequently see two authors, both claiming to be writing accurately of China but presenting distinctly different aspects. It is because each forgets that the particular part of the country with which he is familiar does not necessarily find a counterpart elsewhere and should not be taken as an example of Chinese life as a whole.

This uncertainty in regard to China and its interesting people and problems begins with the name of the country. "China," which is a foreign and not a native term, may cover two quite different territories. It may be applied to what is generally described as China "proper," or the country of the eighteen provinces, or it may include with that area the outlying dependencies of Manchuria, Mongolia, and Tibet, over which the Peking government has exercised a more or less tenuous rule, which, however, has been growing steadily less effective, especially during the past few years, when Russia and Japan have been actually taking territory under their direct control or have been undermining the Chinese power, or, as the people themselves, asserting independence, have refused to acknowledge any longer the suzerainty of Peking.

For the purpose of this address, China will mean China "proper," as extending from the Mongolian line, about latitude 44 degrees, to the China Sea, about latitude 20 degrees, and from the eastern seaboard to Tibet, covering an area of 1,432,795 square miles. A comparison of this figure with 2,970,038 square miles of the United States, exclusive of lakes, and with 1,931,249 square miles of Russia in Europe, will give a mental picture of the

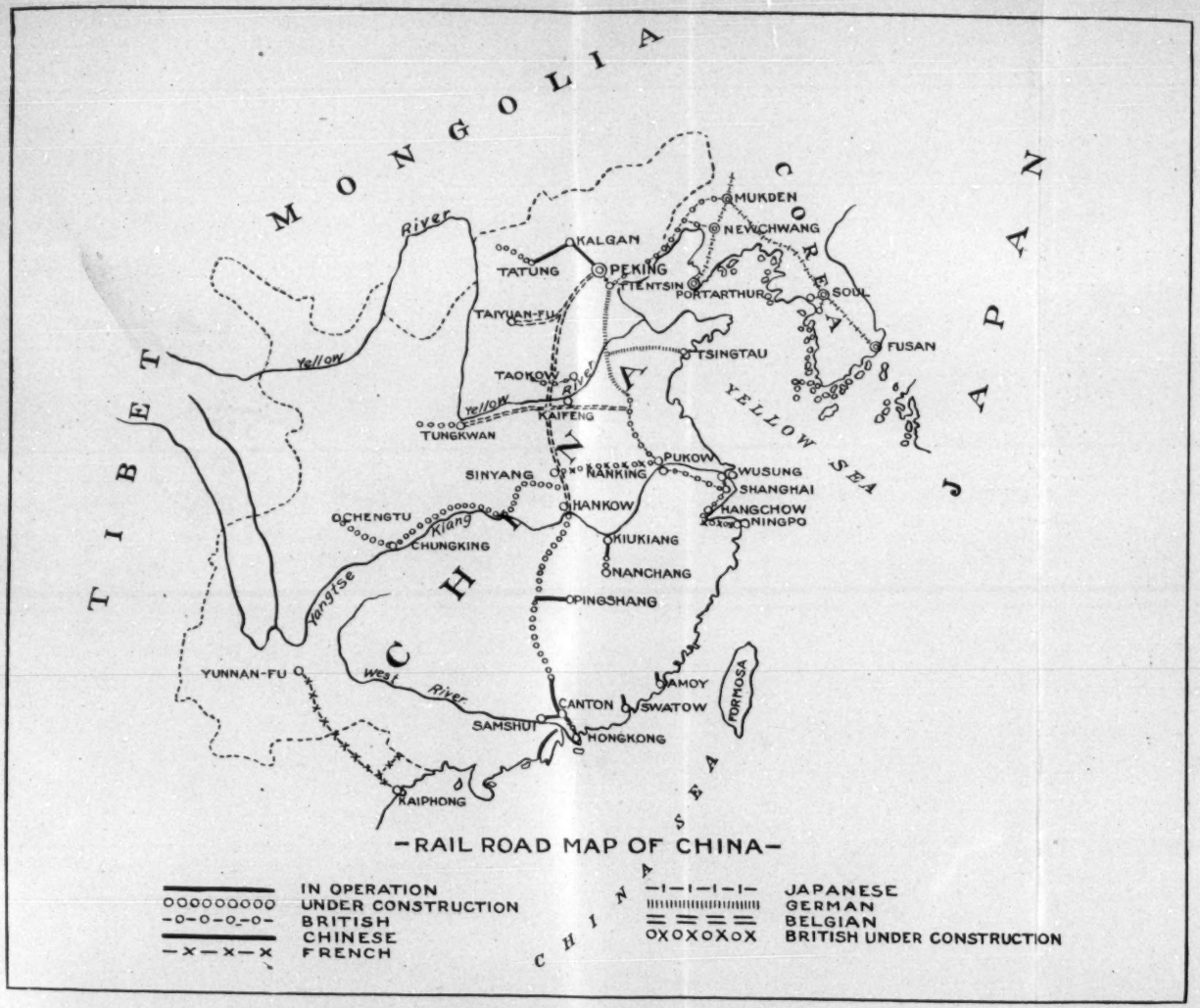
relative size of the country. With its dependencies, the area of the whole Empire is about 4,300,000 square miles, or about one-fifth larger than the whole of Europe.

China reaches north and south from the latitude of northern New York to that of Cuba, and furnishes corresponding ranges

A Chinese city street.

of temperature, but, as the summers in central and southern China are wet and humid, the hot weather is much more enervating than that in similar latitudes in the United States.

Topographically, China is divided into three basins, or watersheds, formed by the three main rivers flowing in parallel lines



-RAIL ROAD MAP OF CHINA-

———	IN OPERATION
ooooooooo	UNDER CONSTRUCTION
-o-o-o-o-	BRITISH
———	CHINESE
—x—x—x	FRENCH
—I—I—I—I—	JAPANESE
|||||||||	GERMAN
= = = = =	BELGIAN
oXoXoXoXo	BRITISH UNDER CONSTRUCTION

from west to east. Of these, the largest is the Yangtze Kiang in the centre—a truly noble stream rising in Western Tibet and traversing some 3100 miles before it reaches the sea. North of the Yangtze is the Hoang Ho—2700 miles long—otherwise known as the Yellow River, and frequently called by the natives "China's Sorrow," on account of the great damage it has done and still does in periods of flood, and also by its erratic behavior in bodily moving its bed from time to time over a distance north and south of 600 miles. South of the Yangtze is the Si Kiang, or West River, with a length of 1250 miles. The existence and location of these rivers are important to keep in mind, as they have determined the main routes of trade in the past and will necessarily greatly influence the routes in the future. The last two are navigable for long distances. Large steamboats ascend the Yangtze to Ichang, about 1000 miles from the sea, where the gorges and rapids prohibit, for the present at least, further progress, except for one small launch which braves the rapids as far as Chungking. During the summer, when the Yangtze is in flood, ocean-going steamers ascend as far as Hankow (600 miles) for cargoes of tea, a minimum depth of from 40 to 50 feet being available for the whole distance.

Of the population of China much has been written and many myths have come to be believed. It has always been the popular idea that China contains a population so vast and so congested that the struggle for existence is intense. The struggle is intense, but this is due not to overpopulation but to lack of profitable diversity of labor and of transportation facilities. We used to be taught that Peking and Canton were more populous than London. The number of people in China has been stated by some authorities to be at least 500,000,000. No real census has ever been taken, nor is one possible with the lax and unscientific methods of Chinese government. Some few years ago the speaker hazarded a guess, based on his own observations in part and partly on statements of others of like opinion, that the population of China did not exceed 200,000,000. At that time the official estimate was nearly 400,000,000. A recent count of families seems to indicate a population of 310,000,000, the smallest official figure ventured in many years, but there is a doubt even in China but that this is an over- rather than an underestimate. The reasons for the error in overstating are many: First, the Chinaman himself is fond of dealing

in large figures. He uses the expression "ten thousand" precisely as the ancient Greeks used the same figure of speech "murioi," or ten thousand, not to denote an exact figure, but a large quantity. So the Chinaman speaks of ten thousand or many tens of thousands to indicate a great or very great number, and, curiously enough, seems to have the impression of being very accurate in so doing. The second reason is that the streets of a Chinese city—Peking excepted—are exceedingly narrow, so that

A Chinese farm-house.

comparatively few people produce a great congestion and give the impression of an immense overcrowding. Third, the Chinese live in villages and cities, and it is with these, more than the open country, that the foreigner is familiar and which, with their overcrowded streets, have led him to accept the loose and inaccurate Chinese statistics. In the country one may travel for miles and at times see but few houses, as the people do not, as a rule, live on their farms, but have been accustomed to herd in villages, chiefly for reasons of mutual protection against robber bands, and in some few districts on account of communal holding of land.

The birth-rate is undoubtedly high, but proportionately high, or perhaps relatively higher, is the rate of mortality, especially among children, and this high death-rate has kept down an excessive increase in population.

Inaccuracy, or perhaps one should say entire failure to appreciate the necessity for, or even the existence of, accuracy, is met at every turn in China. Thus the monetary unit, the tael, has no physical existence as a coin, being nothing more than a weight in silver, and its value is almost as indefinite as its form, there being more than 60 taels recognized throughout the country, differing quite distinctly in value. So it is with the Chinese system of weights and measures. The Chinese foot, the basis of measurement, varies from 8.6 to 27.8 inches, and there are over 100 different kinds of feet in use in China. Apart from the length of the foot varying locally as the tael does in value, each trade has its own standard foot; that is, the carpenter, the mason, the tailor, and the junk builder each has his own foot. The mow, which is the unit of superficial measurement of land, and which in Shanghai is taken at about one-sixth of an English acre, as a matter of fact varies according to locality from 3840 square feet to 9964 square feet. In going through the country it is quite impossible to ascertain distances. As coolies are paid by the li (one-third of a mile) for portage, wholly arbitrary and fictitious scales of distances between villages have been adopted, always in excess of the actual figures, but which the native will not see, or at least admit, are not accurate.

The all-important need of China is greatly-improved means of transportation, not only for its industrial and economic development, but for the amelioration of the condition of its people. To Americans, with more than 250,000 miles of railways in their own country, it is difficult to imagine another country with one-half the area of theirs and twice and a half its population, with fewer miles of railway than there are in the comparatively small State of Tennessee, and without a single highway worthy of the name.

In Northern China, where the horse and cart, and in some districts the camel, are used as means of conveyance, there are a few highways, for the most part leading to Peking, once, perhaps, in fine condition, but now sadly in need of repair. As one goes south the cart disappears, the horse and small pony, bred in Mon-

golia and Manchuria, become scarcer, and the highway dwindles into a footpath only, over which goods are carried on men's backs, or rather on their shoulders, suspended from a bamboo yoke, or on wheelbarrows. Under such conditions traffic, except along the rivers, exists only where it can afford to meet the excessive cost that necessarily is self-imposed. The great, bulky commodities do not move at all. Whole districts are cut off from any benefits arising from contact with the outer world or other parts of

The carts and ponies of North China.

China, and are reduced to self-supply and self-support. If there is a shortage of crops there is a famine; if a surplus, a waste. As there is a lack of diversity of labor, wages are reduced to the minimum figure of barest support of life, and the condition of the people in the interior is in some districts deplorable.

In the past the only outlets of traffic have been China's rivers, reinforced, where possible, by canals, of which latter it is estimated there are 20,000 miles open for boat traffic. As a consequence the Chinese boatman constitutes a large and important

class. Many of them know no other home than their boats, on which, in fact and not rhetorically, they are, born, live, and die. At the treaty ports their junks will be seen lying many deep for long distances along the shore front waiting for cargo or charter. The women on board, in addition to household duties, frequently take their turn at oar or tiller.

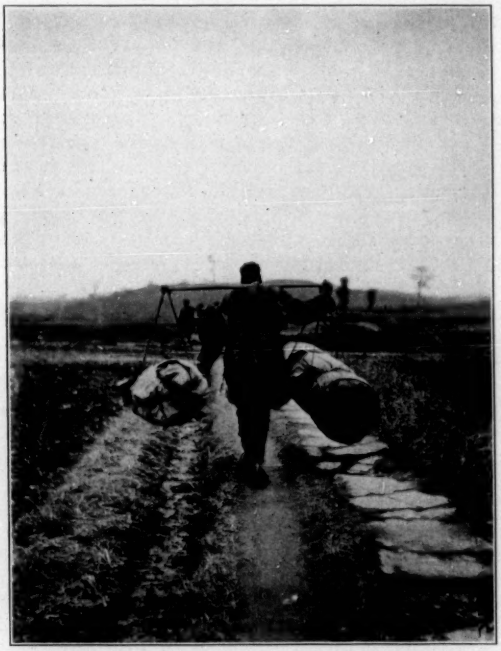
On the lower reaches of the main streams, such as the Yangtze or West, there are large sea-going junks. As the rivers grow smaller and the depths less, the junks gradually are reduced in size to correspond with the decreased facilities, until they become "sampans," or, literally, "three boards," small flat-bottomed boats. The junks go under sail when the wind is fair, and when it is not they lower their large sail, for usually there is but one, and are towed by the crew walking on the river bank and hauling on a towing rope, sometimes made of bamboo fibre, leading from the masthead. When rapids, such as on the upper Yangtze, are reached, boats will collect at the foot of the rapids until there are enough men in the combined crews to haul the junks one by one upstream. By these boats are carried seaward, or to the treaty ports, the interior products, such as coal, rice, tea, etc., and as return cargoes imported manufactured goods.

In order to get these materials to or from the river the small highways act as feeders, on which the conveyances are pony, coolie, or wheelbarrow. A Chinese wheelbarrow is a much more sensible device than its Occidental namesake. Instead of the small wheel being at one end, so that the weight rests partly on it and partly on the man pushing it, the Chinese barrow has a large wheel in the middle, the load being balanced over it on both sides, somewhat in the nature of an Irish jaunting car. The wheel, therefore, bears the whole load, and its large diameter reduces friction. In some districts, to facilitate the wheelbarrow traffic, the highways are paved with long slabs of stone, in which the wheels have worn deep grooves.

Occasionally the demand for food supply is so great that all space is occupied by the rice fields, and sufficient area even for a wheelbarrow path is refused. The necessity for local supply transcends the demands for transportation facilities, owing to the people's ignorance of the latter's value, and the only highways are the winding tops of the dykes making the rice fields, on which coolies walk carrying their burdens. Along the highways inns or

resting places for the men are found at frequent intervals, the path usually leading through the buildings. On the busier routes these inns will be found crowded with coolies.

Between Central China, the valley of the Yangtze, and Northern China there has always been a demand for means of communication, not only for local reasons but to reach Peking, the capital.



Coolie carrying merchandise on a highway in Central China.

These requirements have been supplied partly by highways, but more especially by the Grand Canal running into the Yangtze opposite to Chingkiang. Between the Yangtze valley and Southern China, the necessity for communication being less urgent, the means have been less well supplied than in the north, and

there are but few roads across the dividing mountains. The most important was the route over the Cheling pass, connecting by a portage of 40 miles the headwaters of the Hsiang River, the principal tributary to the Yangtze from the south, with the headwaters of the Pei Ho, or North River, leading to Canton. In previous times this was the great trade route by which the tea and other products of Central China were carried to Canton, thence to be exported or distributed to other ports of China. This highway, explored by the speaker, had been paved and was lined for a great part of its length, not only with inns but with shops, so resembling a city street. At the heyday of its activity it must have presented a busy scene, but to-day the pavement is in bad repair, and the buildings are deserted. The introduction of steam on the Yangtze, opening it to commerce in 1861, has gradually diverted trade to that river and to export from Shanghai rather than from Canton, so that the glory of the Cheling route has passed away, to be restored, however, some day when the railway from Canton north is completed, reference to which will be made later.

A realization of China's need of improvement in interior transit was brought home to its people by the disastrous result of the Japanese war in 1894. At that time China had but one railway from Tientsin northeasterly to the Great Wall. It is true that a small line had been built from Shanghai to Wu-sung in 1876. It was taken over, however, by the Chinese in the following year on payment to its promoters of the cost of its construction, and then destroyed. In 1880 Mr. C. W. Kinder, an English engineer, built for the company owning the Kaiping coal mines a tramway about 10 miles long from the mines at Tongshan to tidewater. In order to operate this line more economically than by horses, Mr. Kinder built a small locomotive out of parts of other machines and which he appropriately named "the Rocket of China." At first the Chinese were much opposed to this revolutionary innovation, and great patience and operation of the locomotive, first within the terminal yard and then in short stretches at a time on the open line, were necessary in order to overcome the native hostility. Through the aid of British capital the line was extended to Tientsin by 1887, and by 1894 had reached Shanhaikwan, where the Great Wall ends at the sea.

At the conclusion of the war, when the Chinese government

officials finally realized and reluctantly admitted that railways were a necessity, a number of projects were at once started. The British interests which were behind the Tientsin-Kaiping mining railway secured the privilege of extending it from Tientsin to Peking, and in 1897 gave through service from Peking to the Great Wall, a distance of 294 miles, and had begun construction beyond the Wall toward Manchuria.

In these earlier negotiations America took part, being represented in the movement by the late Senator Washburn, of Minne-

Junks on the Yangtze.

sota, and a small group in New York, under the lead of the late Clarence Cary. They secured a promise of a concession of the line from Peking to Hankow, which was considered to be one of the most important links to be constructed, as connecting the capital of the country not only with the chief city in Central China but with steam navigation on the Yangtze. The late W. W. Rich, formerly chief engineer of the Minneapolis, St. Paul and Sault Ste. Marie Railway, made a survey of the route in 1896.

A glance at the map indicates the political and strategic importance of this line, and influence was at once brought to bear by every foreign power for its possession.

China at that time was hopelessly weak. Russia, having deprived Japan of its fruits of victory by taking possession of Port Arthur, had obtained from China the right to construct railways in Manchuria and to guard them, which authority afterwards developed into the maintenance of a large army in Manchuria. England, as an offset, had taken the port of Weihaiwei, and Germany, availing itself of the murder of some missionaries in 1897, obtained a "lease" of Kiaochau as compensation, while France and even Italy were desirous of acquiring territory to obtain a foothold, all believing that the long-expected "breakup" was about to take place. It soon became evident that this rivalry might lead to a serious clash, to avoid which the competing nations agreed to establish among themselves the so-called "Spheres of Influence," whereby they recognized, in certain defined areas, predominating commercial and political rights. Thus, to Great Britain was conceded the Yangtze valley, to France the territory in Southwestern China adjoining its own possessions in Tongking, and to Russia the northern section next to Manchuria and extending southerly to Shangtung, which the Germans claimed as the hinterland to Kiaochau.

To permit an important railway line extending from Peking, the capital of the country and on which Russia had already laid envious eyes, to Hankow to pass into the hands of another nation was not to the liking of the European powers, and their influence was at once cast against granting this concession to the American syndicate. Great Britain would have objected to its being given to a Russian syndicate as violating their own agreement on "Spheres of Influence"; France had no right to ask for it; Germany would have been opposed by Great Britain, so Russia, which at that time undoubtedly controlled the court officials in Peking, succeeded in having the concession awarded to a Belgian syndicate, on the grounds that Belgium was a small country and with no desire for territorial acquisition. After the concession had been secured and work was begun it developed that, although Belgians were in nominal control, they had as partners, French banks, and through them Russians, so that Russia, through its allies in France, had succeeded in obtaining what it desired and

what it could not have procured directly; namely, a share in the control of this exceedingly important trunk line.

In the meanwhile, Senator Washburn had withdrawn entirely from the enterprise, and the New York group, now under the leadership of the late Senator Calvin S. Brice, finally procured, in 1898, a concession from the Chinese government for a railway from Hankow to Canton, a virtual extension of the Peking-Hankow line, and which, with it, divided China into halves east and west as the Yangtze divided it into halves north and south.

Junks at a treaty port waiting charter.

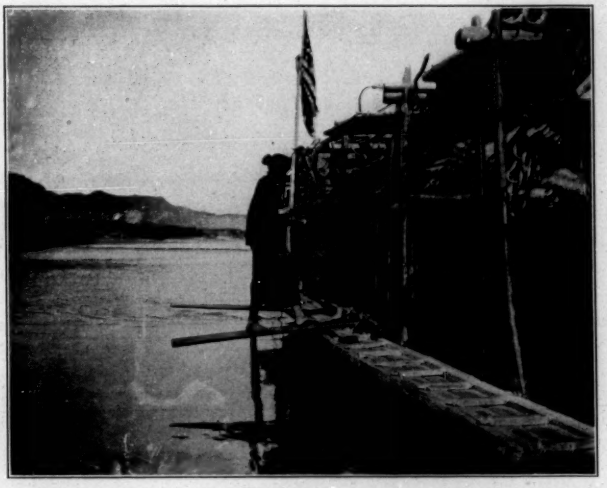
The year 1898 is usually taken as the real commencement of Chinese railway development. It was the year in which the Peking-Tientsin line was put in full operation beyond the Wall, in which the Wusung line (eight miles long) was reconstructed, in which the construction of the Belgian Peking line was actually commenced, and in which the survey of the American line from Peking to Hankow by American engineers was begun.

In China there is no general railway law. Each railway has been constructed under a special concession or contract, executed

with the Chinese government, and obtained after long and very tedious negotiations, during which the promoters have been supported by the minister of their own country and usually opposed by the ministers of all other countries. The first of these concessions was that granted to the Belgian syndicate and whose terms were substantially duplicated in the American concession for the line from Hankow to Canton. These two concessions stipulated that the title to the property to be created was vested in the Chinese, the Chinese government creating an organization, in the case of the American concession, called the Chinese Railway Company of which a government official, Sheng Kung-pao, a man of very great ability, was made Director General. The Chinese Railway Company, through the Chinese Minister at Washington (at that time, Wu Ting-Fang), made a contract with the American China Development Company to provide a loan for the construction of the line, whose construction and equipment were to be supervised by the American company. To repay the cost of the work there were to be issued sufficient Imperial Chinese gold bonds, which bonds were secured by a first mortgage upon the property to be constructed and then the interest and principal, being government obligations, were guaranteed by the Imperial government in the event of the railway not providing sufficient net revenue to meet the service of the loan. These bonds bore five per cent. interest and were to be taken by the American company at 90, the company retaining as profit whatever difference in price above 90 that they could secure in their sale. In addition to this, the American company was to receive as further compensation a commission of five per cent. upon the entire cost of construction, except land and earth works, and for a period of 43 years 20 per cent. of the net profits of the railway. This participation in the enterprise was to be represented by giving to the company debentures or shares to an amount equal to 20 per cent. of the cost of the railway, the remaining 80 per cent. to be retained by the Chinese Railway Company, the latter having the right at any time within the period of 43 years to redeem the American debentures, so-called, at par. The general principles as outlined above form the basis for most of the succeeding concessions.

The latest concession was for the Pukow-Sinyang Railway, executed in 1913, to a British syndicate, and provides for a

definite bankers' commission of 5½ points on the actual selling price of the bonds, and in addition a purchasing commission of five per cent. upon all materials purchased for the line. The funds resulting from the sale of the bonds are to be deposited with a British bank—in this particular case the Hong Kong and Shanghai Banking Corporation. In lieu of the 20 per cent. division of net earnings, which first appeared in the Belgian and American concessions, and was subsequently repeated in the Shanghai-Nanking Railway (a British) concession, a payment of £120,000



Woman at the bar.

was to be made, and then the whole of the net receipts of the line were to be retained by the Chinese government. The concession further stipulated that the engineer, the manager, and the chief accountant are to be British nominees.

Under such conditions the amount of profit in carrying out a Chinese railway concession would seem to be relatively small to the size and importance of the undertaking, and the question might be asked why it should be undertaken at all, as it would

appear that capital could be very much better employed in any one of the British colonies, for instance, or even in the United States, at a very much higher remuneration than 5½ per cent. bankers' commission and 5 per cent. purchasing commission on materials alone. Thus it would certainly appear to an American syndicate. But herein lies the first difference between European and American participation and one of the reasons why American syndicates have not taken as active an interest as those of European countries. For many years past all European nations have been seeking the acquisition of land abroad, into which to divert unemployed population or the excess products of their factories and commercial enterprises, and no European government has hesitated to support openly through official channels the efforts of the people of its country to expand commerce or to seize unoccupied fields, and have even entered into secret alliances with specially-favored groups. This has undoubtedly resulted in developing European trade and at the expense of the American trade where similar government support and alliance have been an impossibility.

As stated above, with the dismemberment of China following the Chinese-Japanese war looming not only possible but highly probable, it was the desire of every European government with oversea interests, in the event of such breakup, to obtain as much territory as possible, and in advance of it to secure the most advantageous position from which to press claims. Railways were obviously the very best opportunity for gaining such a foothold. Leading European powers, therefore, gave their financiers and large contractors not only official encouragement but instructions to secure every railway concession.

As to why the various syndicates were so keen to procure concessions which on the face of them were not very profitable, there were several reasons. One was, perhaps, patriotism, or at least a desire to advance national interest. On the financial side the profits, while on their face small, were nevertheless sure and actually much larger than they appeared to be. Bankers took little risk and no responsibility. The securities to be issued for the cost of the work were the direct obligations of the government, and China has never yet failed to meet its foreign or domestic obligations as they became due. If the railways themselves were profitable, the syndicate received 20 per cent. of its

net profits; if they were not profitable, the principal of the cost of the work and the interest were guaranteed by the government. Bankers, therefore, receive a quite liberal banker's commission for making an issue at a price to be determined by them at which the issue was certain to be taken by the public. Furthermore, after the bonds have been sold the bankers retain in their possession the funds thus received until they are finally expended in construction, or, say, for a period of two or three years, allowing in the interim a smaller rate of interest than the bonds themselves

Chinese wheelbarrow.

pay, which last is a capital charge against construction. The difference between the allowed rate and what the capital would earn was certain to be one or two points per annum. The bankers' profits are, therefore, real and are sufficient to attract bankers in ordinary times.

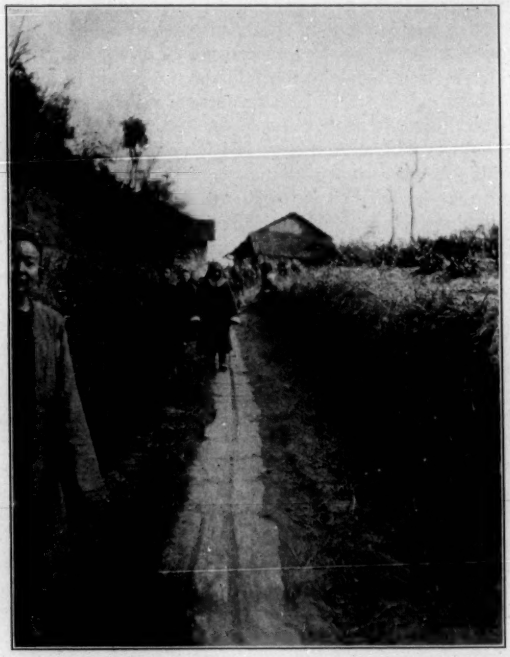
The construction profits are not so immediately apparently generous. The syndicate is limited to a commission of five per cent., in some cases on materials purchased, in other cases on cost

of construction, and, as required by the concessions, tenders for the supply of all material are to be invited and a decision rendered nominally by the Chinese Director General. Every one of these concessions, however, stipulates that the engineer, and in some cases the manager and accountant, shall be of the nationality of the syndicate to whom the concession is granted and to be named by them. This clause is the keystone of the structure. Although the furnishing of supplies is apparently open, in which manufacturers of railway material from any country will be allowed to compete freely, as a matter of fact the specifications can be, and usually are, so drawn as to limit the purchase of materials to certain selected concerns. A combination of bankers, contractors, and railway supply manufacturers, therefore, finds in a Chinese railway concession a very good opportunity to realize profits without risks. The bankers get their commission as stated above, the manufacturers are able to sell their materials at generous figures against very restricted competition, with assured payment, because the actual cash is in the hands of their own bankers, and then, after the railway is completed, to be able to continue to supply railway material on reorders because the management of the railway is in the hands of their own appointees. The five per cent. commission that the company is to receive on the purchase of materials becomes a small factor.

No long argument is needed to prove that such a system of developing the railway system of a great country is highly injurious to its best interests. The promotion has usually been not for the construction of the lines of the greatest local requirements, but those which would most strengthen the political aims of the government of the country of the promoters. From the time construction began and continuing on through the operation of the railway there is no incentive at any point for economy on the part of the promoters, who are the powers in control. Their profits are in proportion to purchases of materials and sales of bonds. The Chinese Director General may make a feeble protest, but it is a futile one to empty air, since there is no one to whom he can appeal. If he objects too strongly, political influence will be exercised for his "promotion" to some other office and his position filled by some one who will limit his activities to drawing his salary and securing appointments for needy relatives, of whom he always has many and who, according to Chinese custom, feel

they have a right to demand support by their favored clansman.

It is a singular fact that any reform of the wasteful system would meet with strenuous opposition by the Chinese themselves. They consider it the very height of wisdom in statecraft to distribute concessions or favors among many nationalities, think-



Highway paved with slabs for wheelbarrows, which have worn a groove in the stones.

ing that in some way they are playing one nation against another, and through many complications—and complications never seem to worry the Chinese mind—that they escape the danger of making any group or few groups too powerful. Moreover, they

are very suspicious of foreign control. As will be shown later, they limit by law foreign participation in mining enterprises to 40 per cent. of the capital, and on the same principle there are no shares in and therefore no stock control of railway companies, thus preventing not only foreign ownership in the railways but even participation in their earnings, with the result that it is nobody's great concern to develop the earnings beyond the point of meeting the interest on the bonds and so avoid the project becoming a charge on the government. For the sake of China it is hoped that some day a more liberal policy will be adopted to result in a wiser method of projecting railways and a more economical one of construction.

Whatever will be the extent and force of European influence in China after the great realignment of the "powers" after the present war is ended, it is obvious that such influence will certainly spring from new political combinations and may be pressed much less energetically, as requirements at home for rehabilitation and repairs of the waste of war will probably deter capital from seeking such foreign investment, and that perhaps European nations for a while will not be so keen in the race to establish "Spheres of Influence." If so, there may arise America's opportunity. But, if the fruits of the opportunity are to be reaped, something more will be required than sending manufacturers' catalogues or even skilful salesmen with the expectation of cabling back profitable orders. China is a rich field. It is one, however, without capital and that has to be carefully developed. Our manufacturers will not and need not be parties to colonizing schemes nor the securing of territorial rights. They must, however, be prepared to establish and maintain a commercial organization at least the equal of similar heretofore existing organizations of other nations, and in that organization to keep in mind the importance of the engineer, who must possess diplomatic ability, commercial acumen, as well as scientific knowledge and experience.

The present railway development in China is shown on the map and consists chiefly of three trunk lines with certain branches: First, the Peking-Tientsin line, which is now extended to Mukden and to Newchwang, where it connects with the Manchurian system; second the Peking-Hankow line, and third, the line from Tientsin to Pukow, on the Yangtze, opposite Nanking.

and from the last-named point to Shanghai, and southwesterly from Shanghai to Hangchow. The Peking-Tientsin-Mukden system, nominally a Chinese government line, is practically under British influence. The Peking-Hankow system, as explained above, is under Belgian-French-Russian influence, while the line from Tientsin through Pukow and Nanking to Shanghai is a combined German and British concession, the Germans taking the northerly half, including the branch to Tsingtau, and the British taking the southerly part. In southern China there is a

Highway on top of dykes between rice fields.

line running from Yunnan-Fu southeasterly to connect with the French railway system in Tongking, and a small section of railway running west and north from Canton owned by the Chinese, being a portion of the lines covered by the original American concession, which was taken over by the Chinese through purchase in 1905, together with a line running southeasterly from Canton connecting with a British line in the British territory of Kowloon, opposite Hong Kong.

The railways existing in China at the present time, as given in "The China Year Book," are:

Railway	Influence	Date opening	Miles operated	Miles under construction
Wusung [1]	B.	1876	10	...
Peking-Mukden [2]	B.	1880	617	7
Peking-Hankow [3]	BL.	1889	816	...
Tayeh Iron Mine	C.	....	17	...
Pinghsiang [4]	C.	1902	65	...
Canton-Hankow	A.C.	1904	138	683
Shantung	G.	1904	310	...
Taokow-Chinghua	B.	1904	96	...
Swatow	C.	1906	30	...
Shansi	BL.	1907	151	40
Shanghai-Nanking [5]	B.	1908	200	...
Shanghai-Hangchow	B.	1908	118	...
Hangchow-Ningpo	B.	....	...	123
Hsuchow-Tungkwan	BL.	1908	400	...
Peking-Kalgan	C.	1909	202	130
Amoy	C.	1910	18	15
Kiangsi	C.	1910	35	52
Yunnan	F.	1910	289	...
Kowloon-Shumchun	B.	1910	23	...
Canton-Shumchun	C.	1911	89	...
Tientsin-Pukow [6]	B.	1910	237	...
Tientsin-Pukow	G.	....	460	...
Total			4321	1050

Meaning of letters: A.—American. B.—British. BL.—Belgian-French-Russian. C.—Chinese. F.—French. G.—German.

The dates of opening show how recent is even the small growth. The miles of railway stated as under construction are of lines, initial portions of which are already under operation, and the remaining under construction to some extent, but with no definite or, for the most part, possible near date for completion. The length of Chinese-owned railways, both within

[1] Taken up by Chinese in 1877, rebuilt and reopened in 1898; now part of Shanghai-Nanking Railway system.

[2] Tongshan colliery line in 1880, opened to Tientsin in 1887; extended to the Great Wall in 1894; to Peking in 1897, and to Mukden in 1903.

[3] Opened through to Peking in 1905.

[4] Built with Chinese capital, now part of Canton-Hankow Railway.

[5] With Wusung Railway, total mileage of system is 210 miles.

[6] Opened through Tientsin to Pukow in 1912.

and without China "proper," is about 6300 miles. The above railways are all of standard gauge (4 feet 8½ inches), except the Yunnan and Shansi Railways, which are of metre gauge, and also a short line, 17 miles long, connecting the Tayeh iron mines with the Yangtze and used only for the hauling of ore.

There are many lines that are projected, for some of which concessions have been granted and officially executed, but, as Chinese affairs under the present system must be looked at through European spectacles, it is doubtful whether all the existing contracts will be carried out immediately, at least as now planned. The lines that are under survey and which are the most likely to be carried out in the near future are:

1. The completion of the original American concession from Canton to Hankow, 683 miles.

2. A line branching off from the Hankow-Peking line running westerly through Ichang, thence up the valley of the Yangtze through the gorges to Chungking, and thence on to Chengtu, about 800 miles; and another line easterly from Sinyang, on the Peking-Hankow Railway, to Pukow.

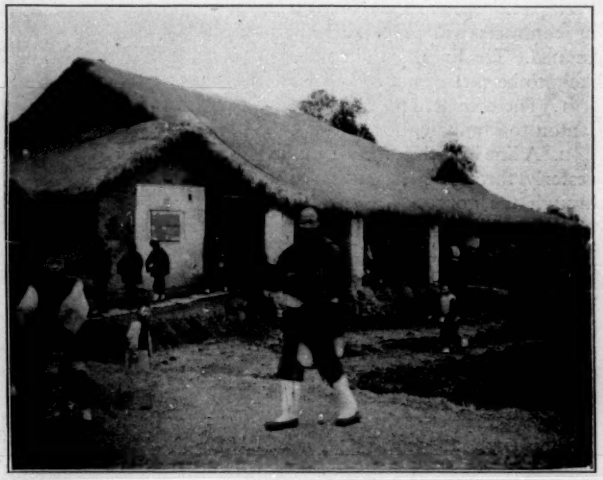
3. An extension of the British lines from Hangchow to Ningpo, on the coast, 123 miles.

4. The Shasi-Singyi Railway from Shasi, on the Yangtze, southwesterly to Singyi, in Kueichow, with branches about 800 miles. This is known as the concession of the Pauling Company, a firm of British contractors.

Of the Yangtze valley line the section from Ichang westerly to Kueichow, on the border line between the provinces of Hupeh and Szechuan, is known as the American section, a sufficient portion of the loan to complete this section having been taken by American banking houses. This section is now under survey by American engineers. The remainder of the line between Chengtu and the Hankow-Peking Railway is covered by French and German grants, respectively west and east of the American section.

In spite of the fact that two of the three great rivers of China are navigable for a large portion of their length, there is no doubt but what the river navigation should be supplemented by the railway communication, and that the same result will be found in China as in the United States, that railways can live and thrive on the banks of great rivers. The line that is now projected in

the westerly portion of the Yangtze valley is along that portion where river navigation, except under the most extraordinary difficulties, is impossible. The Sinyang-Pukow concession is a virtual extension of this proposed railway to Pukow, whence, by ferry to Nanking, the Nanking-Shanghai Railway is reached, thus making, when completed, a through line paralleling the Yangtze from Western China to the sea. This is a highly important link in

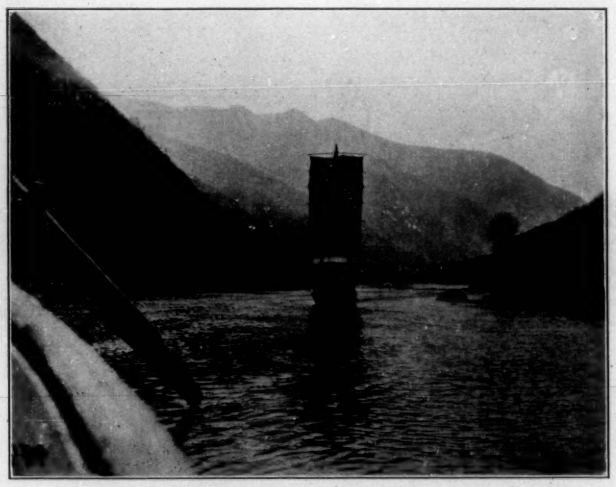


Highway inn for coolies.

China's transportation system and will, if economically constructed, prove profitable. In the same way the line that runs from Canton to Samshui should be extended westerly along the valley of the West River, eventually as far as Yunnan-Fu.

As proving the fact that railway communication can exist along the banks of rivers, the writer points out with pleasure the justification of a recommendation made by him in the construction of the Samshui line. This little piece of railway is some 30 miles long, running westerly from Canton through the manufacturing city of Fatshan to Samshui, and is paralleled the whole

of this distance by water communication, a part of the very complete system of internal waterways leading in all directions from Canton. On these rivers there are found not only the ordinary Chinese junk but a very extraordinary development of the junk consisting of a mechanically propelled one with a stern wheel like a Mississippi River steamboat, operated by gangs of coolies on a treadmill. These boats will carry from one to two hundred passengers and at a speed of from five to six miles an hour. For those who desire privacy and rapid transit there is a small boat, called the "slipper" boat, according to its shape, in



Pei Ho. On this river the boats have double masts.

which the passenger reclines at length in the bow of the boat under a hood and the boat is propelled by three oarsmen. These means of communication seemed to have met all the requirements of the suburbs of Canton, especially where the distance to be travelled from Fatshan to Canton was not over 15 miles and where a railway labored under the disadvantage of having its terminus across the river, necessitating a ferry transfer to the city. The Chinese and many foreigners doubted that a railway would pay in this

district, the lower toll for the river boats being considered as controlling the situation, especially in a country where a few minutes of time were not considered of enough value to save at the cost of real money. These 32 miles were constructed by the American company and now carry about 3,500,000 passengers annually—by far and away the heaviest passenger traffic of any railway in China.

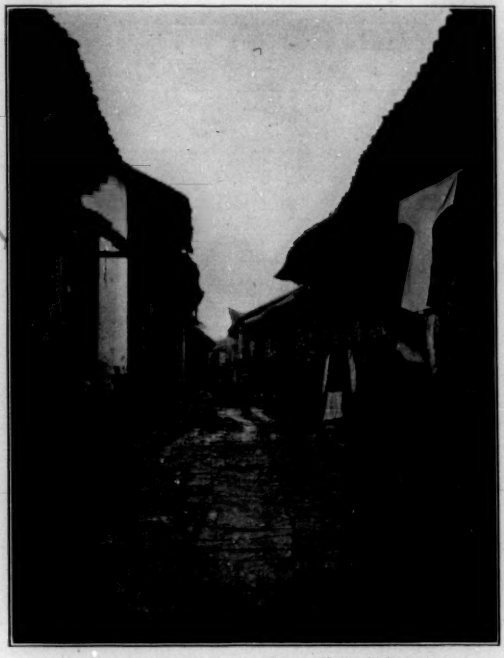
China's mineral wealth is both varied and abundant, but, fortunately, coal is found in great quantities generally throughout

Summit of Cheling Pass.

the country; in fact, there is scarcely one of the eighteen provinces but that contains coal in paying quantities. Through lack of extensive railways and of power-consuming industries, except a few factories at Shanghai and other treaty ports, and on account of the great poverty of the people, consumption of coal per capita in China is very small. Nevertheless, something like 15,000,000 tons are produced annually from the Chinese mines.

Coal is found in three varieties, lignite, bituminous and anthracite, with the intermediate grades of semi-bituminous and

semi-anthracite. At present the greatest producing districts are the metropolitan province of Chili, where the Kaiping mines are the largest and best known, and Shansi. The former field is chiefly bituminous and the latter anthracite. Shantung, through German development of its mines, Hunan, and the province of Kiangsi are also good fields, with annual outputs of a million

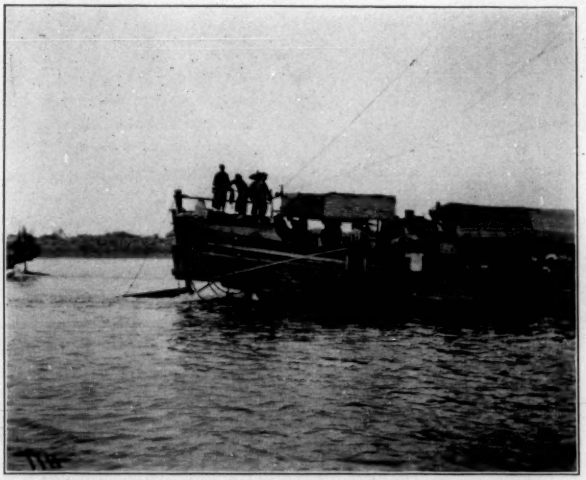


Shops in large part abandoned along Cheling highway.

tons each. In Kiangsi there are located the Ping Hsiang mines, producing an excellent grade of coal, which is coked on the ground and transported now by railway to the Hsiang River, and thence by boat down the Hsiang and Yangtze to be used in China's sole blast furnaces at Hankow. These mines are Chinese owned,

but developed by foreign engineers, and are equipped with thoroughly modern and efficient machinery.

The Chinese native mine is a very singular affair. The native attacks a vein at its outcrop and usually, for some unknown reason, at a point where the vein works down the seam. He drives simply a small tunnel not over five feet high and not over four feet wide, in order to avoid timbering, and carries this downward until he reaches a point where his native pump can no longer handle the inflow of water. When that point is reached the mine

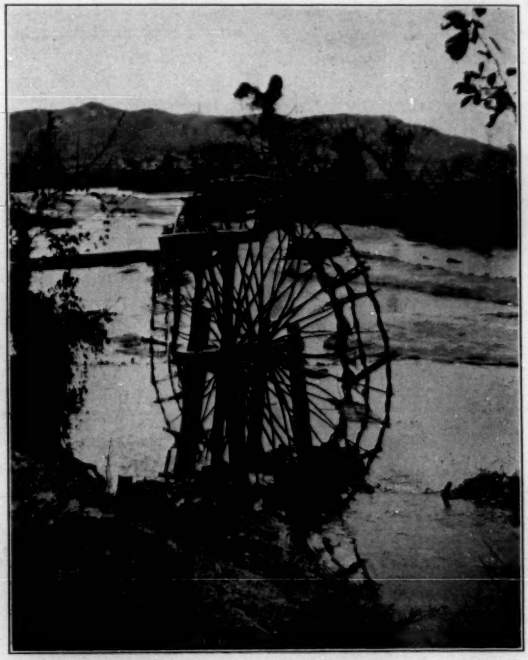


Stern-wheeled junk, worked by men.

is considered as worked out and is abandoned. A Chinese coal mining district, therefore, presents a view on a larger scale somewhat like the mouths of the burrow pits of the western prairie dog, with a multitude of small waste piles dotting the hillsides. From this initial drift there are no side galleries and no rooms. On the floor of the drift are laid two longitudinal timbers, like rails. The coal is loaded into wicker baskets and then hauled up the drift on the rails by manual power. In the Hunan native mines inspected

by the writer the only lighting system was that of joss sticks of punk, giving, of course, nothing but a very faint glow.

A great deal of Chinese coal is coking coal. Some of the anthracite is sufficiently hard and firm to stand the burden of a blast furnace, though nearly all is much softer than its Ameri-



Undershot water wheel raising water for irrigation.

can namesake, similarity existing in chemical composition. A great part of the bituminous coal, however, carries a large percentage of ash, and very much of it is in structure so friable as to produce but a small portion of lump. When the coal deposits can be worked on a large scale and generally throughout the

country, it will be found undoubtedly advantageous to crush most of the coal, wash it, and then either convert it into coke or to compress it into briquettes. The principle of briquetting has already been adopted by the natives, who take the coal dust, mix it with clay, and sell the clay balls in the Chinese cities for local consumption. By washing the coal from the Ping Hsiang mines, from which is made the coke for Hankow iron works, the ash content is reduced from as high as 28 per cent. to 8 per cent., and the sulphur from 0.65 per cent. to 0.1 per cent.

There has never been any approach to a complete scientific study of either coal or other mineral resources of China. About forty years ago von Richthofen made the first attempt to describe Chinese mineral wealth, and his publications, meagre as a first survey in such a huge country must necessarily be, are still referred to authoritatively. The Carnegie Institution of Washington sent, in 1903, a staff, consisting of Messrs. Willis, Blackwelder, and Sargent, who explored a portion of the country and described the geology which they saw. Other writers have also taken it up in part. Until the country has been thoroughly and systematically studied, it is impossible to say how great is China's wealth in coal. Enough, however, has been shown to indicate that China probably possesses at least as much coal as does the United States. Of other minerals China has her share. Iron ore, and of good grade, is found generally throughout the country, but in large quantities only in a few localities. Owing to the fact that up to date there has been but one blast furnace in existence, although others are under construction, the iron ore deposits have been developed on a large scale only at Tayeh, near Hankow, in proximity to the furnace. This ore shows, on analysis, metallic iron ranging from 60 per cent. to 62 per cent., with phosphorus and sulphur as low as 0.05 per cent. Copper is found generally throughout the western part of the country. Tin is found and worked to a considerable extent. Petroleum is found in the northern and western part of the country, and an arrangement has been recently entered into between the Standard Oil Company and the government for its development on a commercial basis. Lead, zinc, and antimony also occur; in fact, of the last metal the world's largest single producer is China. Gold and silver are also found, but up to date only in comparatively small quantities.

The system of developing mines in China is in somewhat better condition, speaking from a legal point of view, than the development of railways. The control of the mining deposits has been placed in charge of the Minister of Industry and Commerce, and a set of rules has been drawn up regulating the opening and working of mines, but, unfortunately, these rules are hedged in with so many Chinese restrictions that they do not attract capital on a large scale. It is instructive as showing the Chinese view of foreign participation, and also amusing, to read the opening paragraph of the mining regulations, to the effect: "The industrial enterprises of China are still in their infancy, and the inclination of the people to launch into industrial enterprises has not yet been developed; therefore, it is inevitable that foreign capital should be introduced, but as the nation has been so weak, it is feared that many interests and privileges will be lost. Consequently, in the question of development by foreign means there should be restrictions. Should there be foreign shares, they should not exceed forty per cent. of the total amount of the capital." The regulations themselves then proceed at length to describe the methods of working the mines, and those more interested in this phase of the question will find them set forth in full in "The China Year Book of 1914."

Although the regulations, on reading, appear to be fair, on a detailed examination by one with a knowledge of Chinese methods there will appear all sorts of opportunities for vexations and delays.

There is one iron works and steel mill, usually spoken of as being located at Hankow, but actually at Hanyang, on the opposite side of the river Han. This plant, though developed by Belgian engineers, belongs, it is believed, to Chinese capitalists, but subject, including the coal and iron mines, to a Japanese held mortgage of 13,000,000 yen. There are two furnaces of 100 tons each and one of 250 tons, and 5 Siemens-Martin open-hearth furnaces. The rolling mill has a capacity of 800 tons, and is used chiefly in making rails. Since China is a great consumer of small bars and the light shapes, rods, wire, nails, etc., it would seem as if a greater profit could be made in rolling such articles rather than rails. For the one there is always a demand, for the other only when railway construction is active. Moreover, rails should be manufactured to strict chemical and physical requirements, while

for the articles mentioned a much greater latitude is permissible, and therefore are better suited to manufacture under Chinese conditions. Chinese pig has been shipped from these works to the United States, an operation subject to repetition, as steamers outbound are always seeking weight cargo to offset the usually light material, such as hemp and matting, China's staple exports, and are eager to carry pig metal at a very low freight rate.

Other lines of constructive development that need serious attention are harbor improvement, irrigation, land reclamation, and river control. Of irrigation the Chinese themselves have done something with crude and simple methods, but of river conservancy work and land reclamation but little has been done, and the opportunity is great. The most serious step in this line is the proposed Huai river improvement, with incidental land reclamation, in northern Anhui and Kiangsu, through which district the Yellow River once flowed. To-day this area of 12,000 square miles, or half as large again as the State of Massachusetts, has practically no drainage, certainly not during a wet season. The soil is exceedingly fertile and capable of raising a generous exportable surplus over all local requirements. As a matter of fact, owing to inundations two crops out of three are lost. Nearly every year for some years past the American Red Cross Society has raised considerable sums to aid the flood-stricken people, and to obviate this it was suggested to drain the territory, reclaim the lands from floods, and remove the cause of the trouble. A favorable report upon this project was made by Mr. C. D. Jameson, American Red Cross Engineer to China, which has recently been approved by a special board of engineers under Colonel William L. Sibert, who made detail plans for the work. This district is not the only one in China where similar improvements can, with profit to the promoters, and should, for the sake of the people, be undertaken.

The great stumbling block to the new development in China is the government itself, which lacks vitality, as it is a government neither of nor over the people. It is not now a democracy, and it has not been for some centuries an all-powerful autocracy. There are no general laws, nor even generally recognized customs, that can deal properly and thoroughly with railways, mines, land reclamation, river improvements, highways, etc. Even if certain government officials technically have the power and authority to

create or to permit the creation of public works, they invariably shrink from exercising their powers until, regardless even of Chinese law, they are assured of the support of the local "gentry," a class too frequently controlled by prejudice and quite ignorant of the remedy for their own local troubles of poverty and suffering, even to the extent of frequently-recurring famines. In governmental matters, as in most other things, the Chinaman just reverses usually-accepted standards. He owes his first allegiance to his clan, afterwards to his province, and last to his nation. The consequence is that a government decree may meet with such violent local opposition as to cause its defeat. This is fully realized by high officials and is perhaps the cause for their timidity and reluctance to come to any decision until local approval is assured. After many years of bitter experience the people have no confidence in the officials, who are regarded—and, unfortunately by past experience, with justification—as engaged in enriching themselves at the people's expense. Fear of officials and antipathy to foreigners have made the Chinese very suspicious of all schemes concocted by these two dreaded classes, and has, on one hand, retarded development and, on the other, kept in force the vicious and wasteful method of Chinese concessions. When this barrier is broken down, when foreign political intrigue is eliminated, when a free field is established for industrial development, there will undoubtedly be in China a great opening for the American engineer. Those who, with friendly eyes, have been watching Chinese affairs with hopeful expectation of such development have on many occasions during the past 50 years thought that the moment had arrived, only to find that but a small advance had been made. Again another crisis has arisen in the great war now in progress. If this will jar China loose from some of its shackles, there will be some gain to offset the otherwise appalling loss.

Magnetic Habits of Alloy Steels. J. A. MATTHEWS. (*Proc. Amer. Soc. Testing Materials,* 1914.)—The magnetic properties of hardened alloy steels are shown to vary with the physical characteristics of the metal. Alloys hardened by quenching in oil give a lower permeability and residual magnetism but a higher coercive force than those quenched in water. The size of the cross-section of the metal also has an influence, varying according to the hardness of the metal.

Study of the Strength of Non-ferrous Castings. L. P. WEBBERT. (*Amer. Soc. Testing Materials,* 1914.)—Tensile tests of Cu-Sn and Cu-Zn alloys were made on test-pieces respectively cast on the outsides of big castings and cut from different portions of solid castings. With Cu-Sn alloys (typically Cu 88, Sn 10, Zn 2) greater tensile strength and elongation were obtained on metal which had cooled quickly than on that taken from the inside of a solid casting, the highest results being given by the cast test-pieces. The use of externally cast test-pieces may therefore give misleading (high) results. Similarly, where little machining was required to make the finished test-piece, the thinner specimens gave the higher results, owing to the cross-sectional proportion of quickly-cooled "skin" being greater. With the Cu-Zn alloys the differences observed with test-pieces taken from different positions were much smaller, and an externally cast specimen represented very closely the strength of the casting as a whole.

Some Notes on Chilled Cast Iron. E. B. TILT. (*Proc. Amer. Soc. Testing Materials,* 1914.)—The variations in the properties of cast iron according to its composition and the effect of chilling were examined with a view to determining the most suitable material for car wheels. Wheels were tested by allowing weights to fall repeatedly from definite heights until a flange was broken off, and also by submitting them to a rapid temperature change. The nature of the defects to which the wheels are subject is discussed. Satisfactory metal can be obtained both from charcoal pig iron and from material prepared from coke pig iron, steel scrap, and ferromanganese. The carbon content should not exceed 3.5 per cent. The metal was found to be brittle in proportion to the degree of chilling.

Lead and the End Product of Thorium. A. HOLMES and R. W. LAWSON. (*Phil. Mag.,* xxviii, 823.)—It has been suggested recently that the end products of the disintegration of uranium, thorium, and actinium are all isotopic with (*i.e.,* indistinguishable chemically from) ordinary lead.

This view has been practically established so far as the end product of uranium (uranium lead or radium G) is concerned, the ratio Pb : U being constant in minerals of the same geological age and increasing with the age in the case of minerals of varying age. Analysis of a number of Devonian minerals and comparison of published analyses of minerals of varying geological age have now shown that there is no constancy in the Pb : Th ratios for minerals of the same age, and hence that thorium E (thorium lead) cannot be a stable isotope of lead, but must disintegrate slowly, losing radiations which have so far escaped detection (the half period of decay has been calculated to be 6×10^8 years by R. W. Lawson, *Nature,* July 9, 1914). It is suggested that the stable end products of thorium and actinium are respectively bismuth and thallium.

MODERN STEELS AND THEIR HEAT TREATMENT.*

BY

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STEEL is an alloy. In its most simple form it is made up of two components: iron and a carbide of iron technically known as cementite and having the chemical symbol Fe_3C.

Commercial steel always has at least four other elements present: phosphorus, sulphur, manganese, and silicon. Phosphorus and sulphur are usually objectionable impurities, while manganese and silicon are required in the finished steel to insure good material. The total amount of these four elements contained in an ordinary commercial steel is less than 1 per cent. The influence of the average variation in all of these impurities is slight upon the physical properties of the steel, compared with the effect of the carbon. We can, therefore, eliminate them in our consideration of the structure of commercial steel.

The carbon is the main factor in influencing variations in the physical properties. It varies from practically nothing in wrought iron to about 1½ per cent. in high carbon tool steel. A variation of 0.1 of 1 per cent. of carbon will affect the tensile strength of annealed steel about 8000 pounds per square inch. This seems rather remarkable, but it is more readily understood when the following facts are considered: the carbon exists as cementite, which is fifteen times as heavy as the carbon of which it is composed. In steel this cementite occurs intimately mixed with about 6½ times its own weight of iron. One part of carbon, therefore, makes up about 112½ parts of this mixture, which is known as pearlite. It is here shown under a magnification of 1200 diameters (Fig. 1).

The black material is the iron, while the white is the cementite. A steel containing 0.1 per cent. carbon is then really composed of about 11 per cent. pearlite and 89 per cent. of iron.

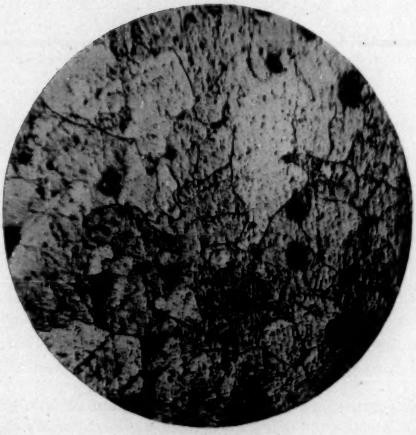
Fig. 2 (150 diameters) shows a sample of iron. It contains

* Presented at the joint meeting of the Mining and Metallurgical Section and the American Society of Mechanical Engineers held January 14, 1915.

FIG. 1.

Pearlite. (1200 diameters.)

FIG. 2.



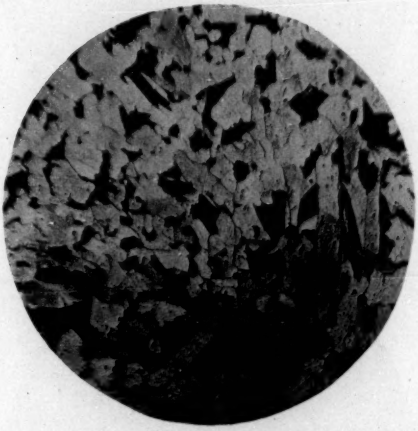
Iron. (150 diameters.)

about 0.01 per cent. carbon, which makes the structure 1 per cent. pearlite and 99 per cent. iron. This pearlite is not visible under this magnification, and, therefore, the material has the appearance of pure iron. The network of lines represents the boundary of individual crystals of iron. As the carbon increases the pearlite areas become larger and the amount of iron smaller.

Fig. 3 (150 diameters) is a microscopic photograph of a steel containing 0.20 per cent. carbon and, therefore, about 22 per cent. pearlite.

Fig. 4 (150 diameters) shows a still further increase in carbon

FIG. 3.



Iron and pearlite, 0.20 per cent. carbon. (150 diameters.)

to 0.40 per cent., which is equivalent to 45 per cent. pearlite and 55 per cent. iron.

Fig. 5 (150 diameters) shows an 0.80 per cent. carbon steel, which contains 90 per cent. pearlite and 10 per cent. iron, while in Fig. 6 (150 diameters) there is no excess iron and, therefore, 100 per cent. pearlite, which is equivalent to a 0.90 per cent. carbon steel.

As the carbon increases above the point necessary to form 100 per cent. pearlite it must necessarily exist as free cementite,

FIG. 4.

Iron and pearlite, 0.40 per cent. carbon. (150 diameters.)

FIG. 5.

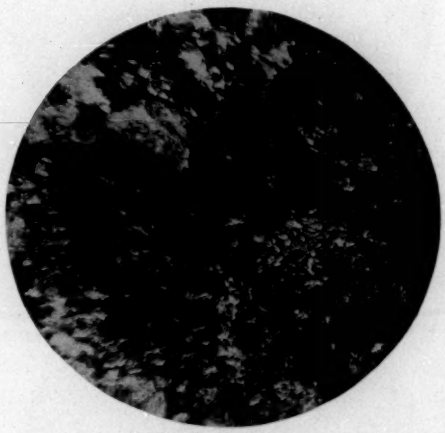
Iron and pearlite, 0.80 per cent. carbon. (150 diameters.)

as all the iron has been taken up to form pearlite when the carbon reached 0.90 per cent.

Fig. 7 (150 diameters) shows a steel with 1.4 per cent. carbon. It consists of 92.5 per cent. pearlite and 7.5 per cent. cementite.

Fig. 8 (150 diameters) is a steel containing 2.5 per cent. carbon. It consists of 24 per cent. cementite and 76 per cent. pearlite. A steel of this high carbon is rare and has no commercial application. White cast iron, which is the material from which

FIG. 6.

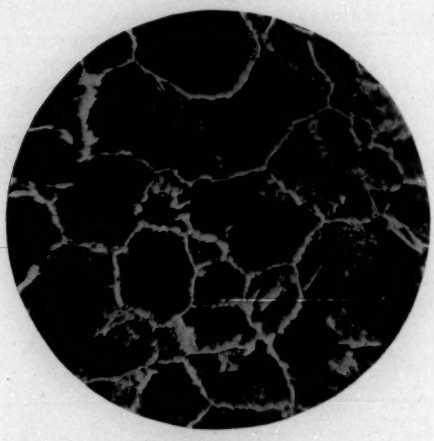


Pearlite, 0.90 per cent. carbon. (150 diameters.)

malleable iron is made, is an impure steel of a carbon content similar to this.

Briefly summarizing the structural condition of a series of steels of various carbon contents, we see that one containing 0.9 per cent. carbon consists of 100 per cent. pearlite. This steel is known as saturated, or, commonly, an eutectoid, steel. A steel containing less than 0.9 per cent. carbon contains pearlite and iron. Such a steel is known as an undersaturated or hypo-eutectoid steel. A steel with more than 0.9 per cent. carbon is known as a supersaturated or hyper-eutectoid steel. Fig. 9 (150 diameters) shows

FIG. 7.



Cementite and pearlite, 1.4 per cent. carbon. (150 diameters.)

FIG. 8.

Cementite and pearlite, 2.5 per cent. carbon. (150 diameters.)

the same piece of steel containing supersaturated, saturated, and undersaturated bands. The carbon contents vary from 2.5 per cent. to 0.2 per cent.

When a piece of steel is pulled apart in a tensile machine the cross-sectional area at the point of fracture is less than that of the original bar. The amount of this difference is known as the "reduction in area," and it is a fair measure of the toughness of the steel. While the meaning of the term "toughness" is open to more or less dispute, we can consider it as the ability of the metal

FIG. 9.

Undersaturated, saturated and supersaturated bands. (150 diameters.)

to distort without causing fracture. For example, a steel which can be bent through an angle of 75 degrees before fracture is tougher than one which can be bent only 25 degrees.

Now if we make tensile tests on a series of steels of increasing carbon contents we find that the tensile strength increases with the increase in the amount of pearlite, but the toughness decreases.

The tensile strength of iron is about 40,000 pounds per square inch. This can be increased by about 700 pounds for each increase of 1 per cent. pearlite.

The reduction in area for pure iron is about 80 per cent., and this is decreased by about 0.5 per cent. for each increase of 1 per cent. pearlite. For ordinary structural purposes a steel which is subject to vibration or shock is not safe with much less than 50 per cent. reduction in area. From these figures it is readily calculated that a steel with 60 per cent. pearlite, which corresponds to about 0.55 per cent. carbon, has a reduction in area of about 50 per cent. Such a steel has a strength of approximately 80,000 pounds per square inch.

Evidently, then, for a steel subjected to dynamic stresses we can safely increase its strength up to 80,000 pounds per square inch by the use of an increased carbon content; however, every additional increase in strength is obtained at the expense of the toughness. A further consideration is the fact that the hardness of the steel, and therefore the difficulty and expense of machining, increases with the increase in pearlite.

A little consideration of the above facts will show us that they are logical and what we should expect. The pearlite is composed of fine plates of pure iron strengthened and made rigid by cementite, which itself is intensely hard and strong, but very brittle.

The pearlite, then, as a mass is strong, but, due to the cementite in it, it is not as tough as pure iron. Pure iron compared to pearlite is weak but tough. A combination of the two will give characteristics consistent with the proportion of the constituents.

It is apparent that in order to obtain greater strength on the steel without increasing the amount of pearlite, or, what is the same thing, the amount of carbon, we could do at least three things: (1) increase the strength of the iron, (2) increase the strength of the pearlite, or (3) increase the strength of both. Practically, these are reduced to two, because anything which increases the strength of the iron also increases the strength of the pearlite to some extent, because of the iron in it.

This can be accomplished by adding to the steel some element or elements which will alloy with either the iron, the pearlite, or both, and increase their strength. A steel containing this extra element is known as an alloy steel. There are two classes of alloy steels: (1) those in which one or more of the normal impurities are made abnormally large, and (2) those in which one or more elements not normally present are added. To the first class belong silicon and manganese steels. To the second

class, which is the more important commercially, belong nickel, chrome, chrome vanadium, chrome nickel, tungsten, and titanum steels.

As typical examples of the two methods of increasing the strength of steel we will consider nickel and chrome steels. Nickel forms a solution or alloy with the iron which is stronger than iron alone. Chromium replaces some of the iron of cementite, forming a carbide of chromium. The pearlite thus formed from the double carbide of chromium and iron is stronger and at the same time tougher than ordinary pearlite formed without chromium. The most widely used nickel steel contains 3½ per cent. nickel, while the common chrome steel has about 1 per cent. chrome. Such a nickel steel will be about 20,000 pounds per square inch, and a chrome steel about 15,000 pounds stronger than a simple steel of the same carbon content. At the same time the toughness of the nickel steel will be about the same as that of a simple steel, while for the chrome steel it will be a little greater. It is apparent, then, that the use of an alloying element to increase the strength of steel is better than to use carbon for the same purpose, as the increased strength is not obtained at the expense of the toughness.

We have seen that the relation between strength and toughness in ordinary steel can be varied by changing the relative amounts, and also the strength or toughness of two substances composing it; namely, the pearlite and iron. In either case this must be done by adding something to the steel: in the first case, carbon, and, in the second, some alloying element.

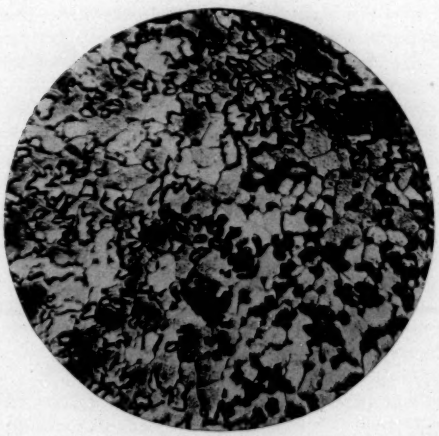
Can we not change the relative amounts of the elements or their strength by some process of heating? We will now discuss this.

Consider the same steel shown in Fig. 3. If we heat this to a temperature of 1000° Fahrenheit and suddenly cool or quench it in cold water, we will find that neither its physical properties nor its appearance under the microscope have been changed; if we increase the temperature to 1100°, we still find no change; nor will we detect any difference until we use a temperature of about 1375° Fahrenheit. Fig. 10 (150 diameters) shows a steel so treated. Comparing it to Fig. 3, we find that the iron is still present and in about the same amount, but the pearlite areas have become more or less rounded.

If we examine this structure under 1200 diameters, the same magnification which we used for the pearlite in Fig. 1, we get a structure shown in Fig. 11. The white areas are the iron, while the dark areas represent what was originally pearlite. It has now apparently coalesced, so that the original cementite and ferrite of which it was composed have merged into a single substance.

The real explanation of the change which has taken place is that the iron which originally composed part of the pearlite underwent an allotropic change at this temperature, and in its new

FIG. 10.



Martensite and iron, 0.20 per cent. carbon, quenched from 1375° F. (150 diameters.)

form it is capable of dissolving to a solid solution the cementite with which it was in contact. This new solid solution is known as austenite, and by the sudden quenching time is not given for the reverse allotropic change to occur completely. It cannot be entirely prevented, and the transition substance which we really obtain is known as martensite.

A steel thus treated is different from the untreated steel in one of its constituents, and is made up of iron and martensite instead of iron and pearlite. Martensite is much stronger but

more brittle than pearlite. We should then expect that our treated steel should be stronger but less tough than the one not treated. The untreated steel of Fig. 3 has a tensile strength of about 55,000 pounds per square inch, and a reduction in area of 65 per cent. The same steel heat treated as just explained has a tensile strength of about 95,000 pounds per square inch and a reduction in area of about 30 per cent. Now these properties are very similar to those of a high carbon steel containing about 100 per cent. pearlite or 0.90 per cent. carbon. In other words, by a sim-

FIG. 11.

Martensite and iron. (1200 diameters.)

ple process of heat treatment we can obtain with a 0.20 per cent. carbon steel the physical strength of a 0.90 per cent. carbon untreated steel.

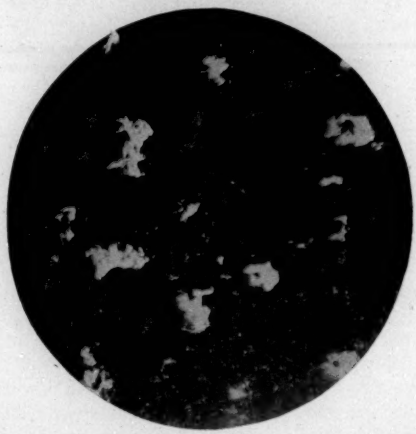
We have just seen that at some definite temperature the pure iron in the pearlite went into a solid solution with the cementite. Possibly at a still higher temperature we could cause more of the iron to go into such a solution.

Fig. 12 (150 diameters) is a photograph of the structure of the same steel quenched from 1440°. It will be noted that the iron has decreased in amount, while the martensite has increased.

FIG. 12.

Martensite and iron, 0.20 per cent. carbon, quenched from 1440° F. (150 diameters.)

FIG. 13.

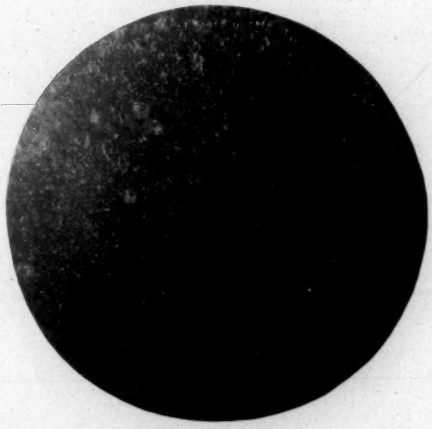


Martensite and iron, 0.20 per cent. carbon, quenched from 1525° F. (150 diameters.)

Apparently, then, as we raise the temperature we increase the saturation point of the martensite for iron; just as in a water solution we can cause more sugar to dissolve by increasing the temperature, so we can here cause more iron to dissolve by increasing the temperature.

Fig. 13 (150 diameters) is the same steel quenched still higher from 1525°. At a temperature of 1565° all of the iron will go into solution and the quenched steel will consist of 100 per cent. martensite. This is shown in Fig. 14 (150 diameters).

FIG. 14.



Martensite, 0.20 per cent. carbon, quenched from 1565° F. (150 diameters.)

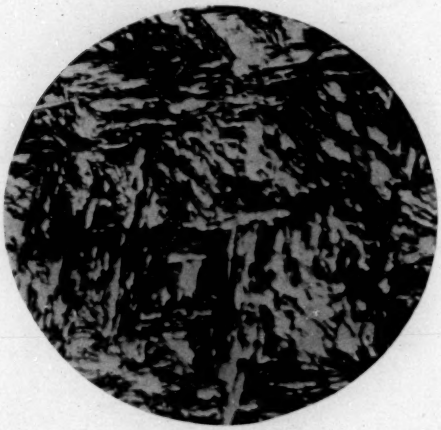
A higher magnification shows the martensite structure to be triangular, as in Fig. 15 (1200 diameters).

Now by comparing the series showing increasing carbon contents in different steels, *i.e.*, Fig. 2 to Fig. 6 inclusive, with the series Figs. 10–12–13–14, which represents the same steel subjected to an increasing temperature of quenching, it will be seen that they are very similar, in that the amount of iron constantly decreases until it becomes zero, while in the increasing carbon series the pearlite increases to 100 per cent. and in the increasing temperature series the martensite increases to 100 per cent.

If we make physical tests on the increasing temperature series, we find that the strength increases, beginning with the temperature of the first change, until final absorption of the iron, while the toughness also increases if the carbon is low. The following table will illustrate this more fully:

Untreated steel			Heat-treated steel, 0.20 per cent. carbon		
Per cent. pearlite	Strength	Toughness	Per cent. martensite	Strength	Toughness
25	55,000	65	25	95,000	30
50	75,000	55	50	98,000	40
75	90,000	45	75	100,000	50
100	105,000	35	100	105,000	55

FIG. 15.



Martensite. (1200 diameters.)

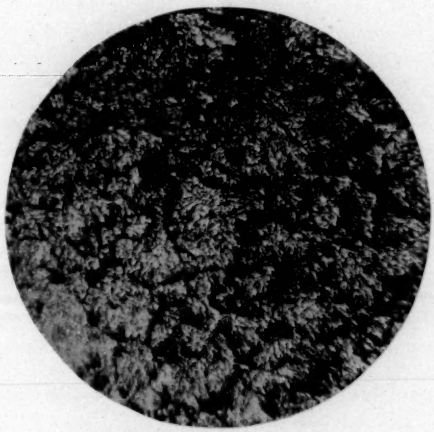
The temperature at which the pearlite first changes is known as the lower critical temperature, and is designated by the symbol "Ac_1." The temperature at which the absorption of iron is complete is known as the upper critical temperature, and is designated as "Ac_3." There is an intermediate critical temperature, which we will not consider now.

It is apparent that of two steels containing different per-

centages of carbon, and therefore different percentages of pearlite, the one containing the more pearlite will have less iron to dissolve, and therefore the temperature of final absorption will be lower. In other words, the upper critical temperature is lowered by an increase in the carbon content. If the steel is all pearlite, *i.e.*, contains 0.90 per cent. carbon, its upper and lower critical temperatures will coincide.

With some steels the best results are obtained by quenching just at the absorption point, while with others a higher tempera-

FIG. 16.



Martensite and troostite, first stage. (150 diameters.)

ture is necessary. The metallurgist must know the amount of this variation for different types of steels.

The heat treatment of an alloy steel is exactly the same in principle as that explained above for plain carbon steels, the alloying elements giving increased strength as well as increased toughness to the heat treated, in the same manner as it did in the untreated steel.

From the foregoing it is apparent that a steel heat-treated to bring out high strength will consist of 100 per cent. martensite,

no matter what amount of carbon there was originally present, nor whether alloying elements were there or not. Evidently, then, martensite will have a varying composition. Under the microscope there is very little difference in appearance, no matter what the composition. Since martensite is really formed from a solution of cementite in iron, a high-carbon steel will form a stronger solution than a low-carbon one, just as we can have a strong or weak solution of salt in water. Alloying elements in the martensite do not cause any difference in its structure any more than a little sugar would cause a difference in the appearance of a salt-water solution. These alloying elements, however, have a very decided influence upon the position of the critical temperature; for example, 0.1 per cent. manganese lowers the upper critical temperature 6 degrees, while it has practically no effect upon the lower critical temperature; 0.1 per cent. chromium raises the lower critical temperature 4 degrees when nickel is absent, but with nickel present it raises it only 3 degrees, but in neither case does it have any appreciable influence upon the upper critical temperature.

The business of the metallurgical engineer is to know absolutely the influence of all elements upon these critical temperatures.

In general, these martensites made from a steel containing more than 0.2 per cent. carbon have not enough toughness for their strength, and to remedy this the steel is given a second low heat, commercially known as a drawing heat, which allows a certain amount of transformation to take place in the martensite, and reduces its strength but increases its toughness. By varying the final heat, an unlimited number of combinations of strength and toughness are available.

Some of these transformation stages have definite characteristics. Fig. 16 (150 diameters) shows one stage. The lighter-colored material is martensite, while the black spots are known as troostite.

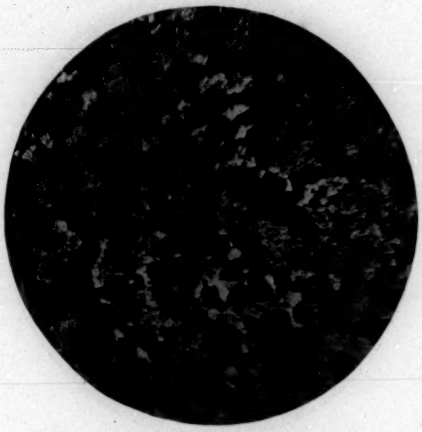
In Fig. 17 (150 diameters) the same constituents are shown, but in a more advanced state.

As the drawing temperature is raised still higher the microstructure of the steel becomes extremely fine and it is known as sorbite. This is really an imperfect pearlite intimately mixed with the iron.

Broadly summarized, the process of heat treatment consists

in transforming an alloy from a mechanical mixture of two substances into a homogeneous solution of a single substance. This very fact gives to a heat-treated steel one of its most valuable advantages over the untreated steel; namely, its ability to withstand repeated shocks or vibrations, or, as it is popularly expressed, "fatigue-resisting power." The reason is obvious: an alloy composed of two dissimilar substances has mechanical boundaries between them. This fact is a source of weakness under repeated stresses, the reasons for which are more or less complicated. An

FIG. 17.



Martensite and troostite, second stage. (150 diameters.)

untreated steel contains these boundaries; a correctly heat-treated steel does not.

There is a still further advantage based upon a different consideration. A steel with a tensile strength of, say, 60,000 pounds per square inch, if subjected to repeated reverses of stress of any magnitude, will finally break after a definite number of these reversals; as the magnitude of these stresses approaches the actual strength of the steel, the number of reversals necessary to cause a break rapidly decreases; as a consequence of this fact, a compara-

tively slight increase in the strength of a piece of steel will increase way out of proportion its resistance to fatigue break. Therefore it is frequently desirable to heat-treat a piece of steel to give it an added factor of safety under shock or alternate stresses, even though its static factor of safety is ample.

In supersaturated steels,—that is, those containing more than 0.90 per cent. carbon,—we have present cementite and pearlite. Most tool steels belong to this class. In the heat treatment of such a steel the pearlite changes to austenite at the same temperature

FIG. 18.

Cementite needles. (350 diameters.)

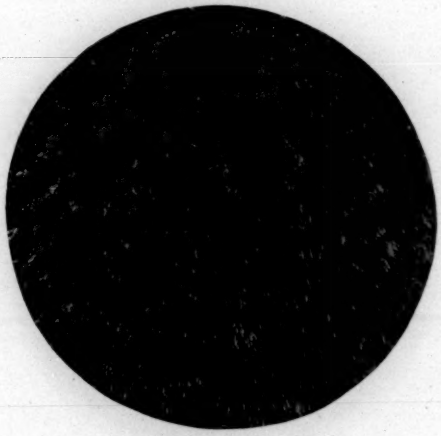
which we found for an undersaturated steel. As the temperature is raised above this point the excess cementite begins dissolving into this austenite, just as the iron did in a lower carbon steel, until at a definite temperature all of it is dissolved, and we have, as before, austenite. The cementite is more sluggish in dissolving into the austenite than the iron, and the reaction requires more time to complete. As we have previously seen, cementite is extremely brittle and hard; it occurs usually as sheets in the pearlite

or thin envelopes surrounding grains of pearlite. These two types are shown in Fig. 18 (350 diameters) and Fig. 7 (150 diameters).

A piece of tool steel which has been previously slowly cooled from above the temperature at which the last of the cementite went into solution will contain the cementite in one of these two forms.

If it is hardened at the lowest possible temperature its pearlite will be changed to martensite, while its cementite will be unchanged. These sheets or envelopes of cementite will cause the

FIG. 19.



Cementite globules. (350 diameters.)

steel to be extremely brittle, and is a source of many of the troubles of the steel user.

Now if we quench from above the upper absorption point we get rid of this cementite, but the steel is somewhat softer because of its absence. The structure of the steel has also been coarsened by the high temperature, which causes it to be brittle. Now if the coarsened steel is again reheated slightly above the lowest hardening temperature, the cementite will be precipitated out of the solution, but, instead of being in sheets or plates, it will occur as fine dots, which give extremely good wear and have practically

no effect of brittleness. A steel thus treated is shown in Fig. 19 (350 diameters). This same arrangement of cementite can be formed by heating the steel to just above the lowest hardening temperature and holding at this temperature for some time.

In an alloy steel the influence of carbon is reduced, and this reduction is greater the higher the percentage of alloy. For structural purposes the carbon of alloy steels rarely exceeds 0.50 per cent.; those containing less than 0.25 per cent. are usually used

FIG. 20.

Core of carbonized steel, single quench. (150 diameters.)

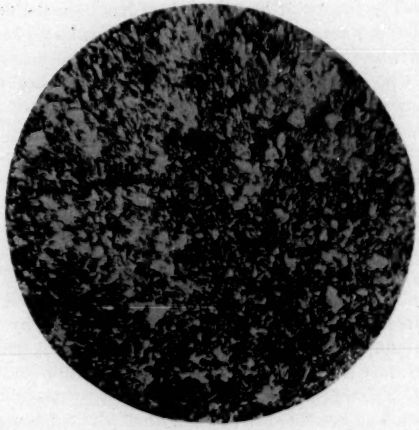
for parts which are to be surface-hardened by the carbonizing process, and above 0.25 per cent. for parts which are to be subjected to stresses which do not require a hardened surface.

In the carbonizing process the outer surface of a low-carbon steel has its carbon content raised by heating in contact with carbonaceous material. The depth of penetration of this high-carbon shell and also the percentage of carbon it contains are functions of the carbonizing material used and the temperature and time of carbonization in general; the outer surface should be

a supersaturated steel, and therefore its treatment comes under that of tool steel, which we have just considered.

To produce a correctly heat-treated, carbonized article we have four functions to consider: (1) the chemical analysis of the steel; (2) the carbonizing material; (3) the time of carbonization, and (4) the temperature of carbonization. These should be adjusted so that the upper absorption point of the iron of the core shall exceed that of the cementite of the case. Under these conditions, if the steel is quenched from above the absorption point of the core this will be entirely martensitic, and at the same time the

FIG. 21.



Core of carbonized steel, double quench. (150 diameters.)

cementite sheet or net of the case will be absorbed, so that it will also be martensitic.

Now in order to obtain the maximum hardness on the surface this cementite must be precipitated, as shown in Fig. 19, by a low quench from the hardening temperature. During this second quench the iron of the core will also be precipitated out in practically the same globular form, with this difference: there being more excess iron than excess cementite in the core, the iron will

precipitate in larger particles and will not have the characteristic globular appearance.

A comparison of the difference in structure of the core of a piece of carbonized steel with a single hardening heat and this double refining and hardening heat is shown in Figs 20 and 21. In both cases we have the same amount of martensite (black) and iron (white) present, but the mixture is much more intimate and fine in Fig. 21 (double quench). This increases enormously the toughness of the finished steel.

DISCUSSION.

MR. H. V. WILLE (*Metallurgist, The Baldwin Locomotive Works*).—The theory of heat treatment has been understood by metallurgists for many years, but this has been largely applied in a practical way only during recent years. Some years ago Dr. Sargeant, who is now connected with the Crucible Steel Company of America, exhibited a small experiment at the Institute which showed in an interesting way the basis of all heat treatment of steel. He heated in a flame of a Bunsen burner a thin plate until he obtained a red spot. Upon removal from the flame he showed that this spot gradually decreased in brightness until a certain temperature was reached, whereupon the fall of the temperature was arrested and the spot glowed with a marked increase in luminosity, showing that some internal change had taken place in the molecular structure in the steel which caused the elevation in temperature in a manner similar to that produced by the combination of sulphuric acid and water. If the steel is quenched at this temperature it will retain its molecular structure, and if examined it will be found that steel so quenched is of maximum hardness, with a less loss of ductility for that particular grade, and, furthermore, the molecular structure will not be changed unless the steel is again heated above this critical or recallescence point. It therefore follows that a steel so quenched can be annealed below this temperature without change in the molecular structure, but with a great increase in ductility. A steel so treated has a much higher elastic limit and a much greater reduction of area than steel which has been subject to the ordinary annealing process. The sole advantage of all of the modern high-grade steel consists solely in an increase in the elastic limit, so that the designer is enabled to reduce the weight or size of any detail by the use of a

higher unit stress, or to increase the factor of safety by the retention of the same unit stress as in a straight annealed steel.

Extremely high elastic limits can be obtained by the use of the various alloys to assist the hardening effect of carbon, such as nickel and chromium, or of the various tertiary alloys, such as chrome nickel, chrome vanadium, or chrome titanium. Steel can be produced having an elastic limit of 150,000 pounds with sufficient ductility to prevent failure by shock by the use of some of these alloys with proper heat treatment, so that engineers are able to design parts with unit stress as high as 100,000 pounds per square inch in place of about 20,000 pounds per square inch for a straight carbon annealed steel. It is hard to grasp the great benefits derived from this enormous increase in the elastic limit. I do not, however, feel that the possibilities of the use of straight carbon, heat-treated steel have been utilized to the fullest extent. This condition results from the fact that metallurgists write the specifications to which steel is purchased, and the chief object of the metallurgist is to secure a steel of maximum ductility. The designing engineer, however, is not concerned about the ductility of the steel, but desires a steel having a maximum elastic limit; but the manufacturer is unable to produce this steel for the designer because of the ductility requirements in the specification.

Mr. James E. Howard made extensive experiments on test on rotating shafts. These results showed that the high-carbon, heat-treated steel withstood as many rotations as the more ductile alloy steel, so that it would appear that equally good results could be obtained by the use of the cheaper high-carbon, heat-treated steel as is obtained from the use of the more expensive and more ductile alloy steel. These views seem to be borne out both by the experience of automobile builders and railroads. I recall going through the principal automobile factories in France, about ten years ago, and was shown with a great deal of pride such parts as axles, steering gears, etc., which were bent double because they were made from a very low carbon ductile steel, but the experience of a few years demonstrated an inordinate number of failures from this grade of steel, and the automobile builders then went to the extreme of using the extremely high grade alloy steel, which gave better results, notwithstanding the fact that it possessed less ductility than the carbon steel.

The railroads met with the same experience, and the first

experiments in the use of steel in substitution for iron were made with low-carbon steel having the same physical properties as wrought iron. A large number of failures followed this substitution, but they were eliminated by the use of steel having a tensile strength of about 80,000 pounds per square inch. This grade of steel is successfully used in railroad service, and there is a gradual tendency to go to even steel of higher carbon having a tensile strength of about 110,000 pounds per square inch. Such steels have been used in an experimental way and have fully proved their value in comparison with the higher-priced alloy steels having greater ductility.

Artificial Twin Crystals of Tin. P. GAUBERT. (*Comptes rend.*, clix, 680.)—If melted tin be allowed to solidify between plane glass surfaces and the polished face be then etched with hydrochloric acid, the outlines of the crystals, some rectangular and others triangular, may be recognized. If solidification has been slow, single crystals may extend over several square centimetres. If the lamina be punctured by a sharp blow with a needle-point, there is produced: (1) on the opposite side a cross in relief with branches equal or unequal in length, according to the orientation of the crystal surface; (2) two or three series of shining parallel bands, 0.5 mm. in width, extending from the point pressed to the edges of the crystal and making an angle of several degrees with the surface of the lamina. The angle between these bands varies with the crystalline orientation of the surface. Whatever the form of the outline of the crystal (*e.g.*, rectangular) as revealed by etching with hydrochloric acid, these bands always bound triangular areas, so that molecules originally arranged in a prismatic face of the crystal undergo re-orientation so as to bound a pyramidal face. The formation of similar bands occurs when a sheet of tin is bent, and is probably the cause of the "cry" of tin.

Calorizing: A Protective Treatment for Metals. H. B. C. ALLISON and L. A. HAWKINS. (*Gen. Elect. Rev.*, xvii, 947.)—Describes, without details, a process discovered by T. Van Aller of heating metals in revolving drums with mixtures containing finely-divided aluminum, by which a surface alloy containing Al is produced. In the case of copper the alloy thus formed is of the nature of aluminum bronze, but is more resistant to the action of heat. Similar results are obtained in the case of iron and steel, and instances are given and illustrated in which treated material has been subjected to a temperature of 900° for four hours without burning. The process seems to be useful as a method of treating iron which is to be used under oxidizing conditions at high temperatures.

THE ORGANIZATION, CHARACTER OF PERSONNEL, SCOPE OF WORK, AND METHODS OF OPERATION AND CONTROL OF A LARGE MUNICIPAL HIGHWAY DEPARTMENT.*

BY

WILLIAM H. CONNELL,

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BEFORE discussing the organization, character of personnel, and methods of operations it might be well to consider the scope of work that should come under the control of a large municipal highway department. The activities coming under the jurisdiction of such a department would be:

The design of all work pertaining to the highways, including parkways, park drives, and small highway bridges.

All engineering work relative to lines, grades, inspection of construction, etc.

The construction and maintenance of all highways, including street pavements, country roads, parkways, park drives, etc.

The placing of sub-surface structures and encroachments, including all underground conduits, pipe lines, service connections, vaults, steps, street signs, stands, etc.

Permits and licenses for vehicles of all kinds.

Street cleaning.

Collection and disposal of ashes.

Collection and disposal of rubbish.

Collection and disposal of garbage.

It is only necessary to glance over the scope and character of the work outlined to become convinced of the fact that, no matter how able the personnel may be, ease of operation, economy, and efficiency in controlling the different branches of work will vary with the character of organization under which the department is operating.

In looking up the definition of the word organization, the two

* Presented at the meeting of the Mechanical and Engineering Section held January 7, 1915.

following interpretations were unearthed from the Encyclopædia Britannica:

> "The process of disposing or arranging constituent or interdependent parts into an organic whole."
>
> "The process of arranging or systematizing, specifically, the process of combining parts into a coördinated whole."

A better definition with particular reference to highway organizations would be:

> "The combination of corelated integral parts into a whole to systematize and simplify the operation, and bring about a maximum of efficiency in the service rendered with a minimum of friction."

Dressed granite block railway intersection on wood block street, Twenty-third and Market Streets.

The perfecting of such an organization is the real problem and grows in importance, depending upon the number of activities and volume of work coming under the jurisdiction of the department. The fundamental principles involved in the planning and operating of a successful organization are the same whether it be a state or municipal highway department, though the activities are of a somewhat different nature. The difficulties to be surmounted depend largely on whether the project consists of planning an organization for a new department, or—which is more

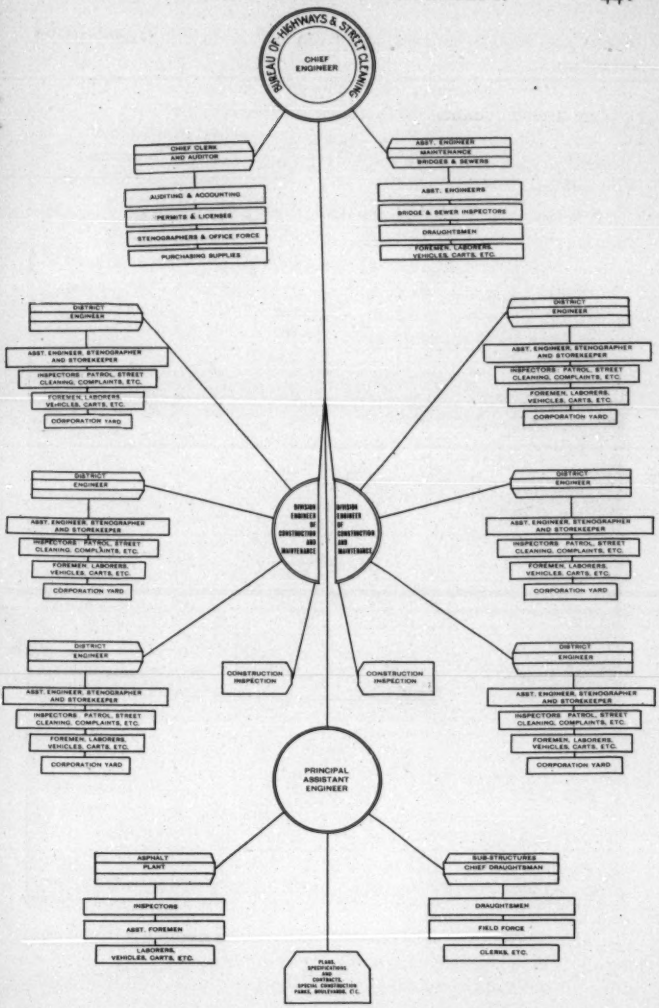
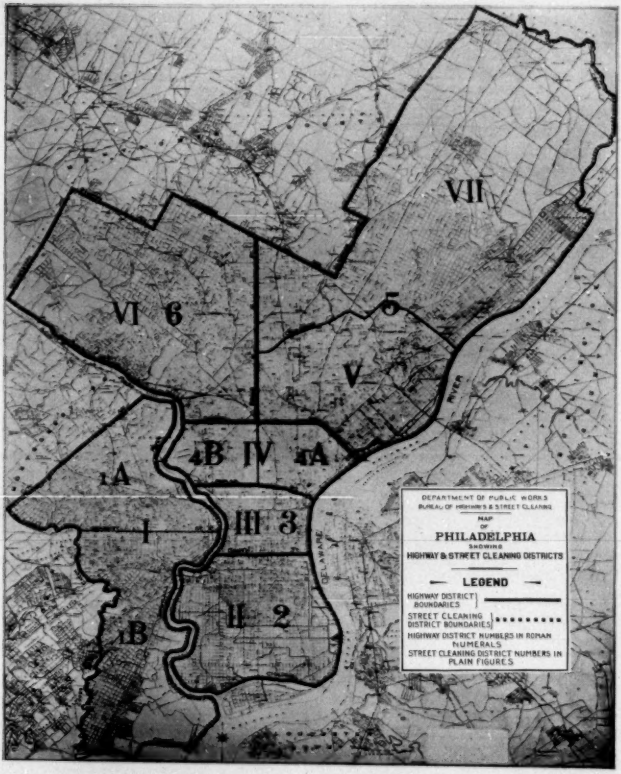


Chart showing the present organization of the Bureau of Highways.

often the case—the reorganization of an existing department. The latter, of course, is the far more intricate problem and one that will be outlined in an endeavor to define some of the principles involved and the difficulties to be met.



The three principal factors to be considered are:

1. The planning of the organization.
2. The character of the personnel.
3. Systematizing the work.

Due weight must be given to each one of these elements.

1. *Planning the Organization.*—This must be done with a view to the future, having in mind the passage of the necessary legislation to put the department on a thorough business basis, and still must be sufficiently elastic to cope with existing conditions, as most of the operations coming under the jurisdiction

Standard sign used on each section of the service test road, giving detailed information on the character of pavement.

of a highway department are of such a nature that they should not be put aside pending proposed legislation or investigations with a view to the reorganization of the department. This, however, is often the case, not only with reference to highway but other municipal, state and government departments, especially in changes of administration, where well-intentioned officials

plunge into reorganization that would ultimately place the work on a higher plane, but which often results in a great financial loss through a cessation of the activities of the departments. It is obvious to all those familiar with management on a large scale

Typical of the condition of a large number of asphalt streets before and after improvement, 1912.

that this cannot be emphasized too strongly as one of the most important considerations in the problem of organization. It is far better to turn the work out under what might not be an ideal organization, using the necessary safeguards to see that it is properly done, than to hold up the work to the great inconvenience of the public, and with a resultant financial loss through interest

Typical of the condition of a large number of country roads before and after improvement, 1912.

charges on appropriations already made and depreciation on existing plant, to say nothing of the loss due to carrying the overhead charges, and the deterioration of roads and pavements due to lack of maintenance.

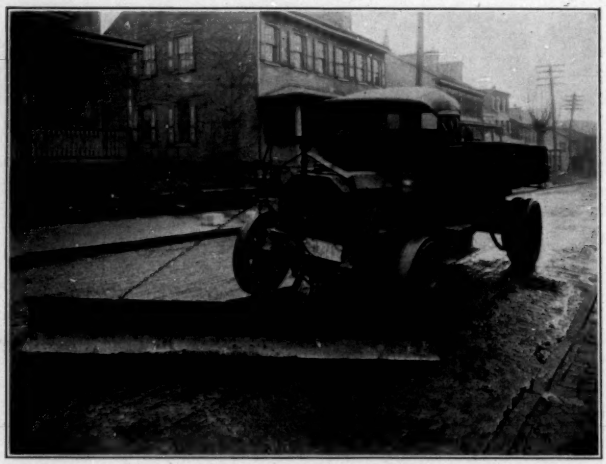
Reorganization, to be constructive, must be brought about gradually. The primary consideration in the planning should be to centralize the control of the work, not only in so far as it relates to the head of the department, but this principle should be carried right down through the organization, which means grouping the activities and combining them where practicable, so that not only will the head of the department be familiar with all the activities, but the entire supervising force will be trained to

Street-cleaning foreman in uniform.

direct all branches of the work. This will do away with shifting responsibility, which is so often the case where the maintenance and construction work are under separate divisions, and will tend to make the organization a more stable and lasting one, as the whole force will be working as a unit and, being familiar with all branches of the work, each and every one will have an equal opportunity to advance.

The tendency of the day is to standardize and control work in a manner that will not only conserve energy and do away with

unnecessary duplication, in so far as individual effort is concerned, but to concentrate our forces so that we can efficiently and economically carry on our operations along the lines of least resistance, as ease of operation is one of the essential factors to be regarded in planning any working organization. There is no step that would accomplish more in this direction than the combination of the highway construction, maintenance, street cleaning, and the collection and disposal of ashes, rubbish, and garbage, under the jurisdiction of the one organization. This



Plows to be used for the removal of snow.

would also have the added advantage of placing the street-cleaning work more generally on an engineering basis, which undoubtedly would lead to more sanitary methods of cleaning that would take into consideration the maintenance and care of the pavements themselves than is likely to be the case where the street cleaning is not under engineering supervision.

2. *Character of Personnel.*—The head of the department should be a highway engineer with executive ability and versed in the principles of organization. These are the logical qualifi-

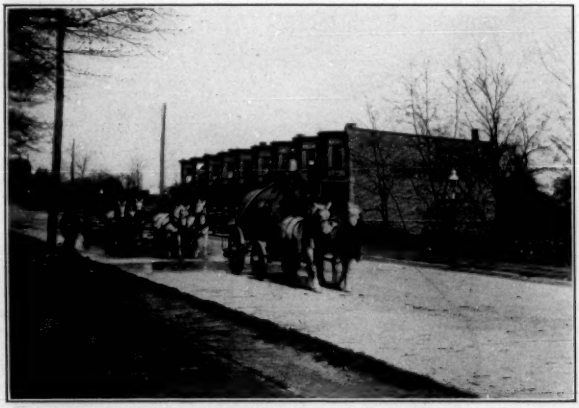
cations necessary to organize and operate such a department. Other than the clerical, stenographic, and audit and account divisions, in the higher grades of the supervising force the entire personnel should be engineers. In the lower grades, such as the inspection, they should be engineers or men with sufficient training in highway work to enable them to intelligently supervise the work coming under their jurisdiction.

The selection of the personnel is one of the most important and in many localities is becoming one of the most difficult problems, due to the methods employed by some of the Civil Service

Typical view of service test road which consists of twenty-six sections of different types of present-day standard materials and methods of construction.

Commissions in determining the qualifications requisite for the selection of candidates for the higher engineering positions where personality, broad experience in controlling work, and good, sound business judgment should be the primary considerations. These qualifications are recognized to be essential for division heads in whom great responsibility is centred and on whom the success of the organization largely depends, and it is obvious that the selections in these cases should be left somewhat to the judgment of the head of the department, who is held responsible

for the work, rather than entirely to the judgment of a Civil Service Board, or through open competition in a technical examination. Civil Service was intended to safeguard the interests of the public and to do away with the "spoils" system, but the principle of Civil Service should be construed in a sufficiently broad manner to permit heads of departments to command control of the work, and this can only be done through a broad application of the Civil Service laws with regard to the selection of division heads in a large department. Considerable stress is laid on this point, as the responsibility of the planning and success of

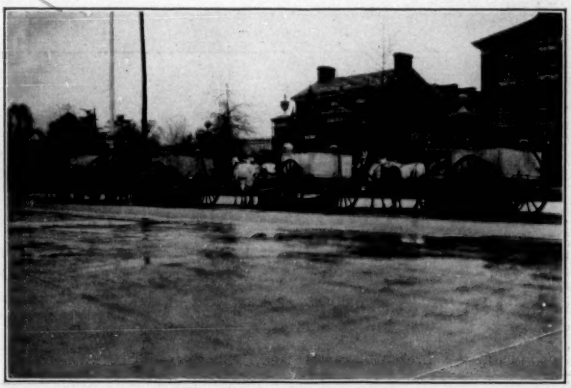


Illustrating method of machine-broom cleaning.

the organization or reorganization in a highway or any other department rests largely with the head of the department. In order to attain the best results his judgment must carry some weight in the selection of the division heads on whom he must rely, as, no matter how correct may be the planning of the organization to carry on and control the work, the ultimate success will depend largely upon the personality and judgment of these men.

The qualifications necessary to make a successful division head vary with the scope and character of work coming under

the jurisdiction of the organization. Just because a man is a good highway engineer does not mean that he will be a success as a division head. Personality and business judgment carry just as much weight as engineering ability. The right type of man for such a position must not be lacking in imagination, and should possess the faculty of not only being a natural leader and commanding the respect of his subordinates, but he should also have their good will, and this means that he must establish a sort of *esprit de corps* in the organization. A man who operates through the good will of his subordinates accomplishes far more



Illustrating method of squeegee cleaning.

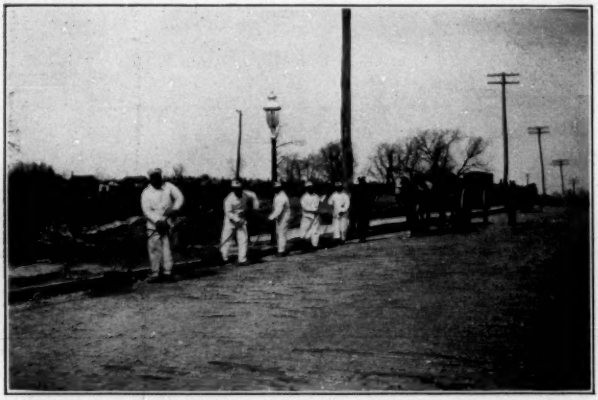
than the stern disciplinarian who lacks the good will and is feared by his subordinates. This is especially true in government, state, or municipal work, where the Civil Service laws and other considerations minimize the authority of the department heads.

3. *Systematizing the Work.*—This requires a very careful study of all the activities of the department from the ground up, and their relation to one another, as the primary consideration should be to do away with as much unnecessary routine as is possible and still have an adequate system of control that embodies

the compilation of all relevant data of value as a guide and a permanent record. Systematizing, of course, means simplifying the work, the bringing about of a maximum of efficiency with a minimum of energy, and in a highway department where the activities are so closely related that there is very apt to be an overlapping of jurisdiction and duplication of work it is obvious that a thorough systematizing of the work is essential.

METHOD OF OPERATION AND CONTROL.

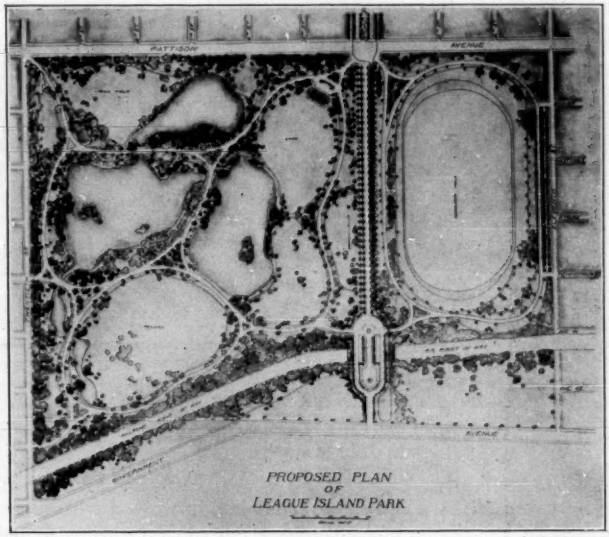
Now, admitting that every department is more or less dependent upon a good organization, let us analyze briefly some of the conditions affecting the operation and control of a large municipal



Method of gang cleaning—following machine-broom and squeegee cleaning.

highway department. The greater part of the work coming under the jurisdiction of such a department, no matter how large or how small, is of a nature that involves so much detail that the real problem is one of maintenance. Therefore, the success from this standpoint is probably four-fifths dependent upon the organization. It is not intended to underestimate the necessity for a good organization to handle the construction, but this work is

of a somewhat definite character and there are more or less well-defined principles that can be followed, both from the standpoint of the office and field, while the maintenance work coming under the jurisdiction of a modern highway department, which, we will assume, embraces all branches of work that is logically highway work, or the care and control of the highways from house line to house line, is an indefinite quantity and may be divided into three classes, namely:



1. Routine maintenance.
2. General maintenance.
3. Emergency maintenance.

For illustration we will consider only the more important functions under these classifications.

1. *Routine Maintenance.*—This includes the cleaning of streets, and this branch of work involves an enormous amount

of petty detail that is only definite in character in so far as the schedule of cleaning is concerned, which usually calls for a general cleaning for each particular street at regular intervals. The amount and character of cleaning, of course, is largely dependent upon the traffic, type of pavement, and density of population. Therefore, relatively speaking, from the standpoint of the state or county highway department, this problem is a comparatively simple one, consisting primarily of the cleaning of country roads, which work embraces scraping the shoulders and keeping the gutters open. The magnitude of this problem varies with the area

Improved granite block pavement in the vicinity of the West Philadelphia station of the Pennsylvania Railroad.

to be covered and the density of population in a given area: from a more or less simple problem on a given country road it looms up into a very important one in a state highway department, and, likewise, from the cleaning of a given street in a small town it looms up into one of the most important problems in a large municipality; and both with regard to the state and municipal highway department it is largely a question of organization. Once the organization is perfected from an administrative standpoint, the work is two-thirds completed; and why?—simply because the work to be done is carried on under a more or less defi-

nite schedule. In a steel plant, so long as the machinery operates smoothly the output of the plant will be up to the standard. Likewise in a routine maintenance organization, such as street cleaning, so long as the organization operates smoothly the work will be properly done; but a poor organization will have the same effect upon the work as imperfect machinery would have upon the output of the steel plant. Therefore, the main problem in routine maintenance of this character is to organize a working force capable of performing the work along the lines of least resistance in an efficient and economical manner.

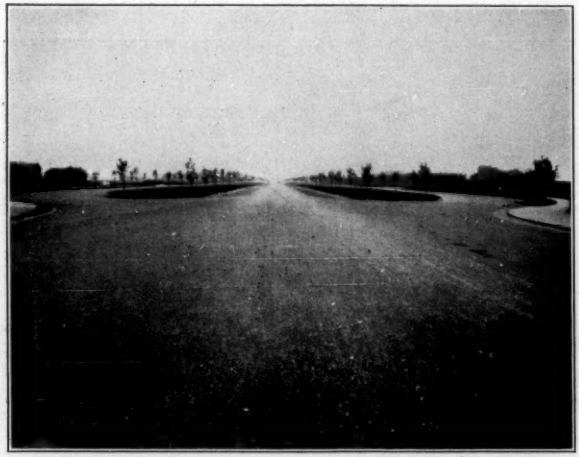
2. *General Maintenance.*—This includes street repairs which

Blockman with bag-carrier, broom, and pan.

are of a distinctly variable quantity and, unlike routine maintenance, must be coped with by an organization of an entirely different kind from that for street cleaning, which organization consists of a regular working force employed all year round and of a more or less military character. The street repair work is usually divided into three classes:

1. Block pavement repairs.
2. Bituminous pavement repairs (mixing method), sheet asphalt, bituminous concrete, etc.
3. Country roads, macadam, gravel, etc., bituminous surface treatments, and earth road repairs.

These classifications involve different characters of work, each requiring special knowledge on the part of those engaged in the actual performance of the physical work. Stone block, wood block, and brick repairs, for example, require skilled laborers who have made a specialty of this work and are employed under the title of pavers and rammers, while repairs to asphalt and bituminous pavements must be performed by men specially trained in this line of work, in addition to the necessary force engaged at the mixing plants. Macadam road repairs, the care of earth



Typical view of the Northeast Boulevard, completed in 1914.

roads, and bituminous surface treatments also require men specially skilled, and, while it is desirable to train the gangs for each particular branch of work under this classification, these subdivisions can be handled by those directly in charge of this division by training the laborers for the particular work to which they are assigned. It readily will be seen that this force, in the first place, can only be employed when the weather conditions are favorable for the work, which makes the organization much more difficult

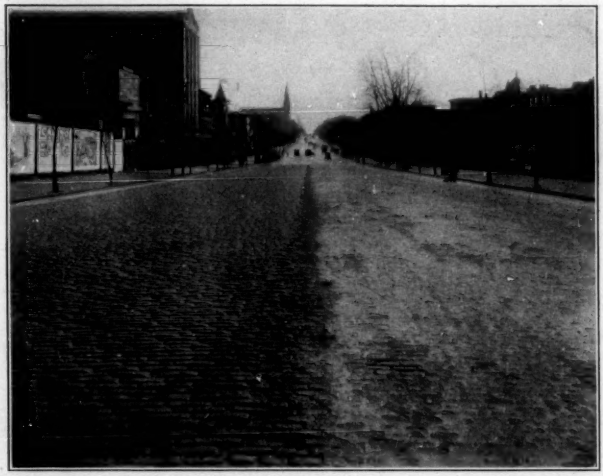
to control and keep up to a proper standard than one composed of men regularly employed all the year round. Moreover, the indefinite character of the work necessitates greater elasticity in the organization than does street cleaning, and makes it a still more perplexing organization to operate with success. In spite of this, the maintenance repairs to streets and roads is the most important branch of work coming under the jurisdiction of any highway department, and it will continue to be the most important,

Typical view of modern brick pavement, cement grout joints.

and this fact is becoming more recognized every day, and will be universally acknowledged when this work is placed strictly on an engineering basis throughout the country. Highway work, not only from a technical but from an organization standpoint, is distinctly an engineering problem, and so soon as this fact is more generally impressed upon the public and all the highway departments are put under the direction and control of engineers our highways will be properly constructed and maintained (in-

stead of being used as a political bugaboo, as is the case in many localities to-day).

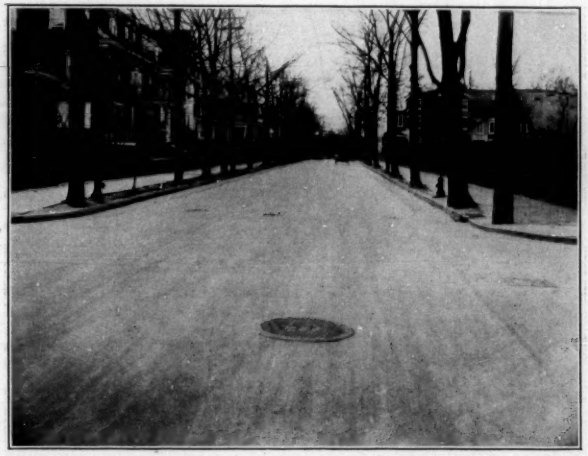
There is no definite schedule for a street repair maintenance organization to work on, and there are no fixed rules that can apply to all repair work other than that a "stitch in time saves nine," and when repairs are required they should be made at once. The materials to be used and the method and manner of making repairs are variable quantities for which only general



Illustrating the difference between the old granite block and same block split in half and relaid, giving a pavement practically as smooth as a new modern dressed granite block pavement.

principles can be set forth, which, of course, means that the organization coping with this work must be well trained and must respect and have confidence in their superiors, and every man, from the laborers to the chief engineer, should take a personal pride in the work. Ways and means of bringing this about is a real problem, and more so than in a routine maintenance organization where the work is of a more definite character; and why?

—because work of an indefinite character opens up a channel for innumerable excuses, and, to be successfully coped with, requires a certain amount of initiative on the part of each and every man, from the laborers to the chief engineer, which makes their good will a necessary adjunct. The men should be taught to understand the relationship between their particular function and the work as a whole. This can be brought about through the installation of unit cost records, which, together with an educational campaign,



Typical asphalt construction with vitrified brick gutters.

consisting of meetings held at stated periods for the purpose of making clear the method of handling the work and each man's part in the work, will bring about a friendly rivalry between the different repair gangs. These meetings mean a great deal, as they set the men thinking, open up a new vision to them, and put them on their mettle, which will ultimately result in improving their opportunities.

3. *Emergency Maintenance.*—This includes snow removal, and it is unnecessary to dwell on the fact that, no matter what

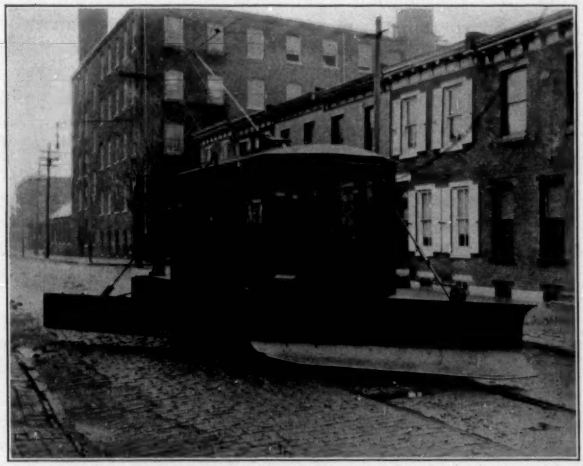
appliances we may have for the removal of snow, the actual performance of the work is dependent upon the efficiency of a thorough and systematic planning of the operations, dividing and subdividing the city into sections covering areas of such a size that the work can be thoroughly and readily controlled by the supervising force. This work comes upon us so suddenly and must be performed in such a short space of time that it requires more supervision probably than any other branch of work, and it is

Typical view of modern wood block pavements in front of hospital.

for this reason that it can be better and more quickly handled by so dividing that each and every one controlling the work will be responsible for a certain definite area. This principle, of course, is true of any city, no matter how large or how small.

The supervising force selected to control the work must be thoroughly instructed before the winter sets in, and imbued with a spirit of enthusiasm and pride in their part in the work. They must be available at all times, keep track of the weather con-

ditions through the main office, where the latest weather reports should always be on file, and, so soon as the indications point to a storm, each and every one in the organization must set to work to get his equipment out on the street at the earliest possible moment. This necessitates his getting in touch with the contractor's teamsters, etc., and all the men assigned to his district, in order that they may start out immediately the snow shows signs of making any headway, which means, of course, so soon as it



Illustrating new plows to be used by the Philadelphia Rapid Transit Company. The adjustable wing will result in cleaning eight feet of the roadway in addition to the area of the track, thus opening up the street for traffic.

begins to cover the pavements. From that time on the whole organization must work day and night fighting the storm, which, after all, is the main problem. The appliances for the removal of the snow are secondary, as, no matter how well designed they may be for the purpose, the problem cannot be successfully coped with other than by fighting the storm, for it is obvious that to wait until it is over would unnecessarily tie up the traffic. Under a

good organization, by using every possible means available for fighting the storm day and night, sufficient progress should be made to keep at least the main thoroughfares open for travel during and after the storm. There, of course, will be innumerable obstacles encountered that may seem beyond the control of those engaged in the work, but it is one of those problems that must be met by an organization imbued with a spirit that cannot be thwarted in accomplishing the result. This is simply the method that has been employed for a number of years by most of the railroad companies, while a great many of the cities have waited until the snow attained a considerable depth or ceased falling before they attempted to clean, which interferes with traffic and makes the work all the more difficult.

A snow fighting organization cannot be conducted along military lines, as it is evident that the work is of such a character that the success depends upon the determination and initiative of those charged with the supervision, and this can only be brought about through a spirit of coöperation, and every man connected with the supervising force must not only carry out the instructions of the head of the department, but use every means in his power to help the head of the department in coping with this problem.

These few illustrations of the difficulties encountered in the control of a large municipal highway department are self-evident and only accentuate the fact that the work must be thoroughly systematized and every possible means taken to control all the functions through a proper and definite procedure, supported by unit-cost records of each individual operation coming under the jurisdiction of the department. These records serve as a basis for determining upon future appropriations. They also serve as a means of control over the operations of the department, bringing out the strong and weak points in the organization and the economy and efficiency with which the work is being performed, both by comparing the different units of the organization with one another, and the different characters of work of the department with like work in other localities. A detailed outline of the procedure and explanation of the forms and unit-cost records required to control the work coming under the different functions would be voluminous to present here, but it is the intention to

present them in detail for most of the work outlined in the 1914 report of the Bureau of Highways and Street Cleaning of the City of Philadelphia.

The following tables, however, are summaries of some of the records compiled for different classes of work, and will serve as illustrations of their importance, purely as a factor in the control of the organization and work. It will be noted that the city is divided into districts, and that the costs in these districts for the same class of work vary somewhat; some of this difference, particularly in street cleaning, is a result of the difficulty experienced in working on streets where the traffic is more congested than in other localities, but the difference in cost in many cases has brought out the strong and weak points of the organization. The records from which these data were compiled will also reveal like conditions in connection with the work of the smaller units of the organization, such as individual repair gangs, etc. (Of course, it must be considered that these tables represent the cost of work performed under an organization that has only recently undergone a complete reorganization, transformed from one with a supervising force of approximately 250 employees, whose yearly payroll was $260,000; that could boast of only one engineer at a salary of $1500 per year, and who was in a subordinate position, to one of which practically all the supervising force are engineers, and in the lower grades men with training in engineering work. This point has been brought out because the cost records are only intended to serve as an illustration of a means of control rather than as a basis for costs of the respective classes of work.)

A very important point, and one that has not been seriously considered in connection with highway engineering, is the relation of the cost of cleaning the different types of pavements to the cost of their maintenance during their economical life. In some instances, where the traffic is heavy and would ordinarily call for a heavy traffic pavement, it might be more economical to lay, for instance, a smooth pavement, such as sheet asphalt, taking into consideration the cost of cleaning.

According to Parsons, Freeman, and Herring's report in connection with their investigation of street cleaning in New York City, they state that the relative difference in cost of cleaning other pavements over and above sheet asphalt pavement per mile is:

Wood block (new)	$26.40
Asphalt block (average condition)	79.20
Brick pavement	105.60
Wood block (old)	132.60
Medina block	158.40
Granite block	211.20
Belgian block	264.00
Cobblestone	1,584.00

The present cost of the cleaning of the respective types of pavements in Philadelphia would indicate that for a 24-foot street it costs approximately $280 per year more to clean a granite block than an asphalt pavement per mile. Assuming, therefore, that on a 24-foot street a sheet asphalt pavement is laid at $2.25 per square yard (which price is probably a little high), it would cost $31,680 per mile. Assuming a life of ten years, the renewal for ten years for resurfacing would cost about $1.25 per square yard (which is also high), would cost $17,600, making a total for construction for twenty years of $49,280.

A granite block pavement of the same width, laid at $3.50 per square yard, would cost $49,280; add to this $5600, which is the difference in cost for cleaning the granite block over and above the asphalt, and subtracting the cost of the asphalt pavement ($49,280), makes a difference in cost for the granite block pavement, including the cost of cleaning, of $5600. This, of course, does not include interest and sinking fund charges, which would add still more to the cost of one granite block pavement over and above the cost of two sheet asphalt pavements for a term of twenty years. These figures are based on machine broom cleaning for granite block *versus* squeegee cleaning for sheet asphalt, and are simply rough calculations based on approximate costs, it being merely the intention to bring out the importance of adding the probable cost of cleaning to the calculated cost of maintenance repairs in making comparisons of the costs of construction and maintenance of the various types of pavement during their economical life. This opens up a field for investigation, as the cost of cleaning will surely be an important factor in the near future in connection with the selection of pavements.

To accentuate the importance and magnitude of the work of a large municipal highway department let us consider, for instance, the value of the pavements under the control of the Bureau of Highways and Street Cleaning in Philadelphia. The initial

outlay, without renewals, represented in the 1587.21 miles of paved streets and roads in this city, exclusive of grading, is approximately $55,000,000. It would seem, therefore, that it is good business to maintain a proper engineering organization to protect this investment, which, together with the cost of the work coming under the jurisdiction of the bureau for the year 1914, totalling $7,855,206, gives an idea of the importance to a community of this function of the city government. The highway department is the principal showcase of a city government—the pavements representing the goods in the window—and it is good policy for any community, city, or state administration to keep them in first-class condition. The civic pride that has been aroused in the last few years throughout the country with reference to the highways in cities, states, and communities has resulted in increasing the importance of highway engineering and raising the standard of our roads and pavements in certain sections where this branch of work is being engineered (not as it is in many localities) by highway engineers. Each day the public is becoming more and more exacting, and any one who pauses for a moment to read the handwriting on the wall will agree that the inevitable outcome will be that this work throughout the entire country will soon be placed under the control of highway engineers.

The following is a tabulation in detail of the amount and character of contract work in force or on which bids were received during the year 1914, with the amounts thereof:

Character of work	Number of contracts	Amount
Paving	233	$1,278,240
Paving (private)	61	179,650
Repaving	56	340,309
Resurfacing (asphalt)	69	344,000
Resurfacing (vitrified block)	6	95,100
Resurfacing and surfacing macadam	87	705,690
Repairing and patching asphalt	1	250,000
Repairing and patching macadam	3	5,350
Curb and footway repairs (city to pay)	2	9,546
Curb and footway repairs (property owners to pay)	1	....
Constructing curb on Twenty-first Street	1	1,000
Grading	166	639,204
Parkway	4	5,890
League Island Park	1	490,000

Character of work	Number of contracts	Amount
Northeast Boulevard	2	$803,481
South Broad Street Boulevard	1	194,733
Sprinkling streets	3	25,000
Furnishing teams	7	52,000
Furnishing and operating dredge	1	2,531
Furnishing and delivering oil, sand, gravel, etc.	5	27,800
Furnishing and delivering stone	1	3,290
Collection and disposal of garbage	1	288,588
Cleaning streets	8	1,711,424
Disposal of waste and rubbish	2	.....
Repairing and painting bridges	8	46,330
	730	$7,498,156

In addition to this contract work, work of a value of $357,048 was done by city forces in repairs to streets and roads, bridges and sewers, and meadow banks, bringing the total value of work under the direction of this bureau for the year 1914 up to $7,855,206.

DEPARTMENT OF PUBLIC WORKS
BUREAU OF HIGHWAYS AND STREET CLEANING.
Philadelphia, Pa.

Comparison of Street Cleaning Cost Data per 1,000 sq. yds.

District	Machine Broom Cleaning: Cost computed from Special test data	Machine Broom Cleaning: Cost computed from District daily reports	Squeegee Cleaning: Cost computed from Special test data	Squeegee Cleaning: Cost computed from District daily reports	District
1–A	.202	.208	.146	.144	1–A
1–B	.220	.194	.118	.127	1–B
2	.262	.290	.101	.103	2
3	.233	.302	.205	.167	3
4–A	.253	.251	....	.225	4–A
4–B	.236	.226	.127	.202	4–B
5	.228	.336	.122	.129	5
6	.239	.232	.123	.176	6
Average unit cost	.232	.269	.134	.151	Average unit cost

The above does not include water.

Water at 0.04 per 1000 gallons = 0.004 (Mach. Broom), 0.010 (squeegee) per 1000 sq. yds.

The above costs include operating and direct supervision only and are based on the following:

Foremen	$2.50 per day.
Gangmen	1.75 per day.
2-horse sprinkler	5.00 per day.
Machine broom	5.50 per day.
Squeegee	6.00 per day.
Dirt cart	3.50 per day.
Dirt wagon	5.00 per day.

Street Pavements and Country Roads in the City of Philadelphia, December 31, 1913.

Character	Miles	Square yards
Granite block	348.32	6,573,246
Asphalt (sheet)	504.57	7,457,393
Asphalt (block)	7.39	69,950
Vitrified block	171.57	2,517,755
Wood block	8.16	186,848
Cobble	7.13	73,704
Rubble	4.63	65,213
Slag block	8.13	78,071
Cement and Granolitic	11.03	54,242
Total	1,070.93	17,076,422
Bituminous macadam roads	60.98	703,548
Waterbound macadam roads	242.10	2,799,488
Total macadam roads	303.08	3,503,036
Grand total (improved pavements and macadam roads)	1,374.01	20,579,458
Earth roads	213.2	.....

DEPARTMENT OF PUBLIC WORKS—BUREAU OF HIGHWAYS.
UNIT COSTS FOR REPAIRS MADE BY CITY FORCES, 1914.

Resurfacing Waterbound Macadam.

District	Sq. yards	Labor	Teams	Material	Total	Average unit cost
1	9,021	1,620.66	1,121.00	2,805.90	5,547.56	.615
2	700	130.32	15.75	131.25	277.32	.396
3	.....	.....	.....	.....	.....	....
4	.....	.....	.....	.....	.....	....
5	10,075	1,136.64	1,682.00	2,299.73	5,118.37	.508
6	32,702	3,361.24	674.03	6,781.43	10,816.70	.331
7	55,951	3,994.05	3,704.75	11,743.11	19,441.91	.348
Total....	108,449	10,242.91	7,197.53	23,761.42	41,201.86	.38
7	3,378	123.21	105.25	106.99	335.45	.10

Spiked up and rolled, very little material used.

Patching Waterbound Macadam.

1	9,609	2,113.45	1,511.36	1,445.15	5,069.96	.528
2	.....	.....	.....	.....	.....	....
3	.....	.....	.....	.....	.....	....
4	.....	.....	.....	.....	.....	....
5	4,477	824.74	679.58	575.12	2,079 .44	.464
6	14,357	1,701.42	599.89	1,419.09	3,720.40	.259
7	9,449	1,095.71	1,117.67	1,428.66	3,642.04	.385
Total....	37,892	5,735.32	3,908.50	4,868.02	14,511.84	.383

DEPARTMENT OF PUBLIC WORKS,
BUREAU OF HIGHWAYS AND STREET CLEANING,
Philadelphia, Pa.

Summary Showing Detail Costs of Bituminous Surface Treatment Work, Season 1914.

	Average per sq. yd.		Average labor cost per sq. yd.					Average material cost per sq. yd.			Aver. total cost per sq. yd.	Average total cost per sq. yd. First and second treat.	
	Gal. bit. mat.	Lbs. cov'g mat.	Sweeping		Chip'g	Clean up	Total labor	Bit. mat.	Cov'g mat.	Total mat.		1914	1913
			Hand	Mach.									
Refined coal tar, heavy (Tarvia A), first treatment...	.464	16.2	.0051	.0017	.0046	.0026	.0140	.0373	.0175	.0548	.0688	.0641	.0824
Refined coal tar, heavy (Tarvia A), retreatment.....	.291	15.6	.0039	.0009	.0112	.0024	.0182	.0244	.0167	.0411	.0593		
Refined coal tar, light (Tarvia B), first treatment....	.389	15.7	.0069	.0024	.0067	.0047	.0207	.0258	.0168	.0426	.0633	.0566	.0658
Refined coal tar, light (Tarvia B), retreatment.....	.314	14.6	.0044	.0011	.0055	.0034	.0144	.0200	.0155	.0355	.0433		
Refined water gas tar, light (Ugite), first treatment..	.299	16.3	.0030	.0004	.0039	.0026	.0099	.0248	.0171	.0419	.0518	.0509	.0598
Refined water gas tar, light (Ugite), retreatment....	.301	13.4	.0034	.0006	.0067	.0003	.0110	.0239	.0148	.0388	.0500		
Asphalt cutback, first treatment.....	.346	17.5	.0057	.0021	.0061	.0042	.0181	.0420	.0188	.0618	.0799	.0738	.0868
Asphalt cutback, retreatment.....	.297	18.5	.0026	.0014	.0057	.0039	.0136	.0309	.0223	.0532	.0677		

Gravel	Cost per 2000 pounds delivered on road	$2.14
Trap Rock Chips	Cost per 2000 pounds delivered on road, —1.749, 2.30 and 2.35—Average	2.30
Tarvia A per gallon applied—.08½	Ugite cold, per gallon, applied	.08
Tarvia B, per gallon, applied—.07	Ugite hot, per gallon, applied	.09
	Asphalt cut back, per gallon applied	.11½

All classes bituminous material....	Total square yards treated	1,034,470
	Total gallons applied	334,377
	Total pounds covering material	14,435,347
	Total cost	$60,407.23

DEPARTMENT OF PUBLIC WORKS
BUREAU OF HIGHWAYS AND STREET CLEANING
Philadelphia, Pa.

Street Cleaning Cost Data—Machine Broom Work Per 1000 Square Yards

District	Computed from special test data																From dist. daily reports	
	Granite block				Brick				Wood block				Asphalt				Average unit cost all classes	Average unit cost all classes	District
	Traffic			Unit cost	Traffic			Unit cost	Traffic			Unit cost	Traffic			Unit cost			
	Heavy	Med.	Light		Heavy	Med.	Light		Heavy	Med.	Light		Heavy	Med.	Light				
1–A	.337	.183	.200	.201	....	....	.208	.208	....	....	....	....	....	....	.198	.198	.202	.208	1–A
1–B	....	.237	....	.237	....	....	.218	.218	....	....	....	....	....	....	.147	.147	.220	.194	1–B
2	.290	.259	....	.281	....	.225	....	.225	....	.200	....	.200	....	.187	....	.187	.262	.290	2
3	.255	.220	....	.238	....	....	....	....	.217	....	....	.217	....	....	....	....	.233	.302	3
4–A	.282	.250	.200	.254	....	.226	....	.226	....	.264	....	.264	....	....	....	....	.253	.251	4–A
4–B	.283	.231	.209	.261	....	.221	....	.221	....	....	....	....	....	.243	.178	.186	.236	.226	4–B
5	.305	.227	.207	.250	....	.231	....	.231	....	....	....	....	....	.194	....	.194	.228	.336	5
6	....	.259	.233	.251	....	.277	.178	.210	....	....	....	....	....	....	....	....	.239	.232	6
Average unit cost				.245				.217				.217				.187	.232	.269	

The above does not include water—Water at 0.04 per 1000 gallons=0.004 per 1000 square yards.
The above includes the cost of the removal of the street dirt averaging 0.23 cubic yard per 1000 square yards. Cost of 0.087 per 1000 square yards.

The above costs include operating and direct supervision only and are based on the following:

- Foremen, $2.50 per day
- Gangmen, $1.75 per day
- Machine Broom, $5.50 per day
- Dirt Wagon, $5.00 per day
- Dirt cart, $3.50 per day
- Sprinkler, $5.00 per day

Table Showing Estimated Cost of Bituminous Treatment Work on Waterbound Macadam Roads for Philadelphia and Vicinity.

	Average per sq. yd.		Average labor cost per sq. yd.					Average material cost per sq. yd.			Av. total cost per sq. yd.
	Gal. bit. mat.	Lbs. cov'g mat.	Sweeping		Chip'g	Clean. up	Total labor	Bit. mat.	Cov'g mat.	Total mat.	
			Hand	Mach.							
Refined coal tar, heavy (Tarvia A), first treatment	.500	18	.0051	.0017	.0053	.0035	.0156	.0425	.0193	.0618	.0774
Asphalt cutback, first treatment	.500	18	.0051	.0017	.0053	.0035	.0156	.0583	.0207	.0790	.0946
Refined water gas tar, heavy (Ugite), first treatment	.500	18	.0051	.0017	.0053	.0035	.0156	.0450	.0207	.0657	.0813
Refined water gas tar, light (Ugite), first treatment	.500	16	.0051	.0017	.0053	.0035	.0156	.0400	.0193	.0593	.0749
Refined coal tar, light (Tarvia B), first treatment	.500	16	.0051	.0017	.0053	.0035	.0156	.0350	.0193	.0543	.0699
Refined coal tar, heavy (Tarvia A), second treatment	.333	15	.0036	.0010	.0045	.0025	.0116	.0283	.0161	.0444	.0560
Asphalt cutback, second treatment	.333	15	.0036	.0010	.0045	.0025	.0116	.0388	.0173	.0561	.0677
Refined water gas tar, heavy (Ugite), second treatment	.333	15	.0036	.0010	.0045	.0025	.0116	.0300	.0161	.0461	.0577
Refined water gas tar, light (Ugite), second treatment	.333	14	.0036	.0010	.0045	.0025	.0116	.0267	.0150	.0417	.0533
Refined coal tar, light (Tarvia B), second treatment	.333	14	.0036	.0010	.0045	.0025	.0116	.0233	.0150	.0303	.0499
Refined coal tar, heavy (Tarvia A), third treatment	.200	14	.0036	.0010	.0042	.0025	.0113	.0170	.0150	.0320	.0433
Asphalt cutback, third treatment	.200	14	.0036	.0010	.0042	.0025	.0113	.0236	.0161	.0397	.0510
Refined water gas tar, heavy (Ugite), third treatment	.200	14	.0036	.0010	.0042	.0025	.0113	.0180	.0150	.0330	.0443
Refined water gas tar, light (Ugite), third treatment	.200	13	.0036	.0010	.0042	.0025	.0113	.0160	.0139	.0299	.0412
Refined coal tar, light (Tarvia B), third treatment	.200	13	.0036	.0010	.0042	.0025	.0113	.0140	.0139	.0279	.0392

Based on the following labor and material costs

Tarvia A..... .08½ per gallon applied on road
Tarvia B..... .07 per gallon applied on road
Ugite hot..... .09 per gallon applied on road
Ugite cold..... .08 per gallon applied on road
Asphalt cut back..... .11 per gallon applied on road
Gravel.....2.14 per 2000 pounds delivered on road
Trap rock chips.....2.30 per 2000 pounds delivered on road

Laborer.....$2.00 per day
Foreman.....$4.00 per day
All labor costs are based on the average labor costs of the Philadelphia Bituminous Surface Treatment work.

DEPARTMENT OF PUBLIC WORKS—BUREAU OF HIGHWAYS

UNIT COSTS FOR REPAIRS MADE BY CITY FORCES, 1914

Granite Block on Sand and Concrete Bases

District	Sq. yards	Labor	Teams	Material	Total	Average unit cost
1	32,989	8,781.65	927.20	1,144.32	10,853.17	.329
2	23,927	8,450.70	1,680.83	1,371.56	1,1503.09	.481
3	43,766	10,532.64	2,647.14	2,257.25	15,437.03	.353
4	50,541	14,632.08	1,494.40	2,865.20	19,991.68	.396
5	53,084	13,020.03	2,489.50	2,029.71	17,539.24	.33
6	23,214	6,774.36	1,158.24	245.66	8,178.26	.352
7	244	77.00	10.00	.....	87.00	.357
Total.....	227,765	62,268.46	11,407.31	9,913.70	83,589.47	.367
Vitrified Brick on Sand and Concrete Bases						
1	6,142	1,639.20	257.78	813.95	2,710.93	.441
2	3,271	1,100.90	244.23	502.13	1,847.26	.565
3	651	213.51	67.30	88.77	369.58	.568
4	2,094	586.19	193.81	584.87	1,364.87	.652
5	3,690	962.19	239.84	220.76	1,422.79	.386
6	23,206	5,803.77	1,093.82	624.31	7,521.90	.324
7	.....	.....	.....	.....	.....	....
Total.....	39,054	10,305.76	2,096.78	2,834.79	15,237.33	.39
Asphalt						
On bituminous base:	4,480	2,330.72	490.77	167.20	2,988.69	.667
On concrete base.	2,470	1,301.76	237.20	72.30	1,611.26	.652

Automatic Signals on Victoria Bridge. R. F. MORKILL. (*Canad. Elec. News,* xxiii, 35.)—The paper describes the new alternating-current automatic signalling put into service by the Grand Trunk Railway across the Victoria Jubilee Bridge. The bridge is about 6600 feet in length, and has one electric and two steam roads. On account of heavy traffic the block sections have been made comparatively short, ranging from 2500 to 3600 feet. The signals are operated by single-phase, 110-volt, 60-cycle induction motors. Wireless control circuits are used with polyphase three-position relays, the local coils receiving energy at 12 volts from transformers on the track. Track transformers also supply energy for track circuits and signal lamps; all signals are lighted electrically by 2-candle-power, 2½-watt tungsten lamps. High- and low-tension wires are supported on a single cantilever cross-arm. On the bridge structure great difficulty was experienced in properly sighting the signals, but this was met by mounting the blade at the bottom of the spectacle casting.

Use of the Hering Furnace for Electric Brass Melting. G. CLAMER and C. HERING. (*Metallurgical and Chem. Eng.*, xii, 648.)—The Hering furnace is based on the use of the "pinch-effect" for heating and circulating the metal, and the author in this paper describes its application to brass melting. It is pointed out what a large amount of heat is carried out of the heating holes in the furnace bottom ("the resistors") effectively by the rapidly-flowing metal; it exceeds that of a row of electric arcs in these holes. At present about 25 to 50 kilowatts are converted into heat in each hole (or roughly about 90,000 to 200,000 B.T.U., equivalent to 20,000 to 45,000 kg.-cals. per hour), with the probability that this can be considerably increased. The correct proportioning of these holes and of the current is of great importance. These proportions are quite different for brass and for steel. The furnace must be especially designed for each metal, though variations in the composition of brasses and bronzes can be allowed for in the same furnace by regulation of the electric current. Even copper, with its very low resistance, can be melted commercially in these furnaces without requiring impracticable proportions. The higher the electrical resistivity of a metal the better the proportions become. The power factor of the furnace, even with 60 cycles, is not low, being 80 or 90 per cent.; the loss incurred is chiefly in the transformer, and should be avoided with a better design. In a steel furnace, with a frequency of 25, the power factor was practically 100 per cent. The Hering furnace has so far been used for melting very light brass and bronze chips, which gave trouble in the fuel furnaces. In melting many tons of these light, curly, and oily brass chips, with much mechanically mixed iron, they cast (in the form of clean ingots) nearly 8 pounds per kilowatt-hour delivered to the furnace transformers, equal to about 12.5 kilowatt-hours per 100 pounds poured. But there were various losses which can be avoided in the future. Short runs, with clean ingot charges, indicated that, even with the easily avoidable excesses in the losses, 10 pounds per kilowatt-hour could be obtained in this furnace—hence, in better designs, even still better efficiencies than this can reasonably be expected. But this figure depends largely on the amount of superheat required by the particular foundry man. The economy of the electric melting could be greatly increased by preheating the charge with a fuel flame, preferably in an auxiliary furnace, to only such a temperature at which no oxidation takes place. Comparisons are made between the operation costs of fuel-fired and electric furnaces for brass melting. Taking as an average 38 cents per 100 pounds for coke furnaces and 20 cents for the electric, the saving in a plant melting 20 tons per day would be nearly $22,000 per year of 300 days; or for oil furnaces at 43.2 cents and electric furnaces at 20 cents the saving would be nearly $28,000 per year, which should be credited to the first cost of the electric furnace.

IRON A FACTOR IN THE WORLD'S PROGRESS.*

BY

JOHN BIRKINBINE,

Consulting Engineer.
Member of the Institute.

THE European war, while drawing heavily upon the resources affecting industries of contending nations, also seriously influences conditions in countries throughout the world not engaged in hostilities, threatening lasting effect and possible future changes in many phases of development. For this reason a discussion is offered of the relative positions of the leading countries which produce pig iron or supply the requisite raw materials for its manufacture, and to indicate past as well as present conditions a period of at least four decades has been chosen as covering practically the era of greatest industrial growth.

Prognostications as to future conditions are not attempted, but analyses of the data presented may suggest possibilities for nations now prominent or others wherein the development or utilization of the above commodities is less pronounced, while similar studies of other industrial specialties may indicate even greater changes.

Iron ore and coal hold leading rank among mineral resources whose development has been and is coincident with the world's progress, for countries possessing these abundantly, or utilizing them liberally, are the dominant nations.

The United States produces more coal, more iron ore, and more pig iron than any other nation, and her strongest competitors are the European countries now at war, for they are each an important factor in the supply of some or all of the above, and, together with the United States, are depended upon for

85 per cent. of the iron ore,
96 per cent. of the pig iron supply of the world,
89 per cent. of the coal.

They are also the most active producers of varied forms of iron and steel manufactures, a large proportion of their inhabi-

* Communicated by the Author.

tants being skilled and efficient in mine, furnace and mill work.

A disturbance as momentous as that produced by the European conflict is far-reaching in its effect upon industrial progress, and its influence may be expected to continue long after peace is declared: for animosities do not cease with the suspension of active hostilities.

Consideration of iron as a factor in the world's progress necessarily is dependent on statistics, but, to relieve the discussion of voluminous tables, charts are presented on which are traced the conditions prevailing since 1870 in iron ore, coal, and pig iron productions of important nations. The quantities recorded are in long tons (2240 pounds), except for countries using the metric system, where the amounts are given in metric tons (2204 pounds).

Iron Ore.

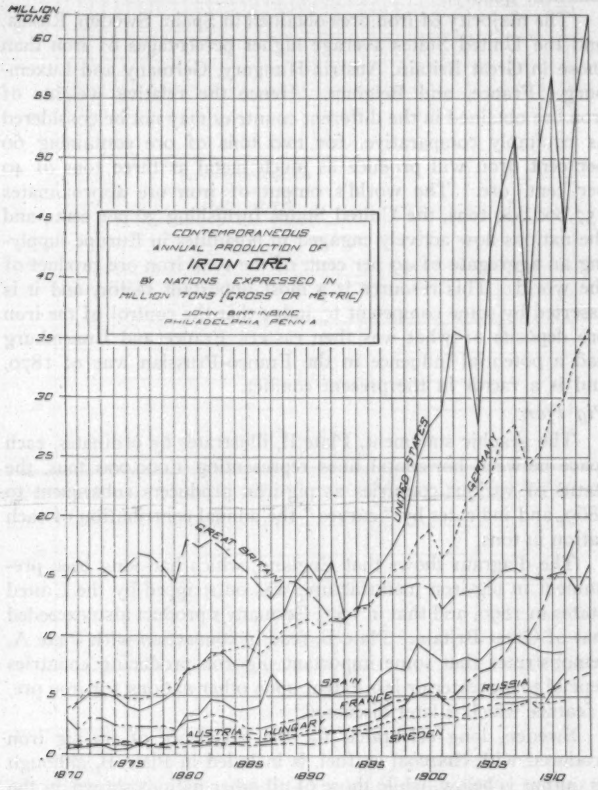
Plate A illustrates the annual production of iron ores in the countries which have been or are prominent in supplying this mineral. The ordinates indicate in tons (the space between two longitudinal lines representing five million tons) the outputs of each country, designated by a particular form of line; the abscissæ show the years. By tracing the "curve" for any country, its production in a given year is found, or its contemporaneous position with other iron ore producing nations is demonstrated. Thus Plate A shows that Great Britain was the largest contributor of iron ore until 1889, when the United States took first place, and since 1895 Germany has exceeded the output of Great Britain. The contemporaneous contributions of the three nations were practically equal in the years 1893 and 1894, subsequent to which time the advance of Germany and of the United States has been more pronounced than that of Great Britain. In late years the iron ore output of France has materially advanced. It will be noted that the maximum annual productions of iron ore were, for the United States 1913, Great Britain 1882, Germany and Luxemburg 1913,[1] France 1912, Spain 1907, Russia 1911 (?), Sweden 1913, Austria-Hungary 1911 (?).[2]

[1] The statistics of Luxemburg, which supplies liberal quantities of iron ore and coal, have been officially combined with those of Germany.

[2] (?) intimates that no authentic records are available subsequent to the date mentioned.

In addition to the countries designated in the graphic representation, the islands of Cuba and Newfoundland are each supply-

PLATE A.



ing about one and a half million tons of iron ore annually, and smaller amounts are mined in Canada, China, Greece, Italy, Algeria, Belgium, Tunis, Australia, India, Japan, Norway,

Mexico, Brazil, Chile and Korea. Iron ore exists in minable quantities in most of the geographical divisions of the earth and in some of these there are known reserves of enormous extent and of excellent quality.

The majority of iron ores obtained in Spain, Sweden, Russia, and the United States average higher percentages of iron than those in Great Britain, Austria-Hungary, Germany and Luxemburg, France, and Belgium. Hence the relative weights of iron ore obtained in the different countries may not be considered as equitably comparative, for two tons of ore containing 60 per cent. iron will produce as much metal as three tons of 40 per cent. ore. The world's output of iron ore approximates 157,000,000 tons, the United States furnishing 36 per cent., and the nations now actively engaged in hostilities in Europe supplying an aggregate of 49 per cent. of the total iron ore product of the world. This resource is a most important factor, and it is asserted by some competent to judge that the control of the iron ore deposits of what was then eastern France and Luxemburg had a potential influence in the Franco-Prussian war of 1870, and is a factor in the present conflict.

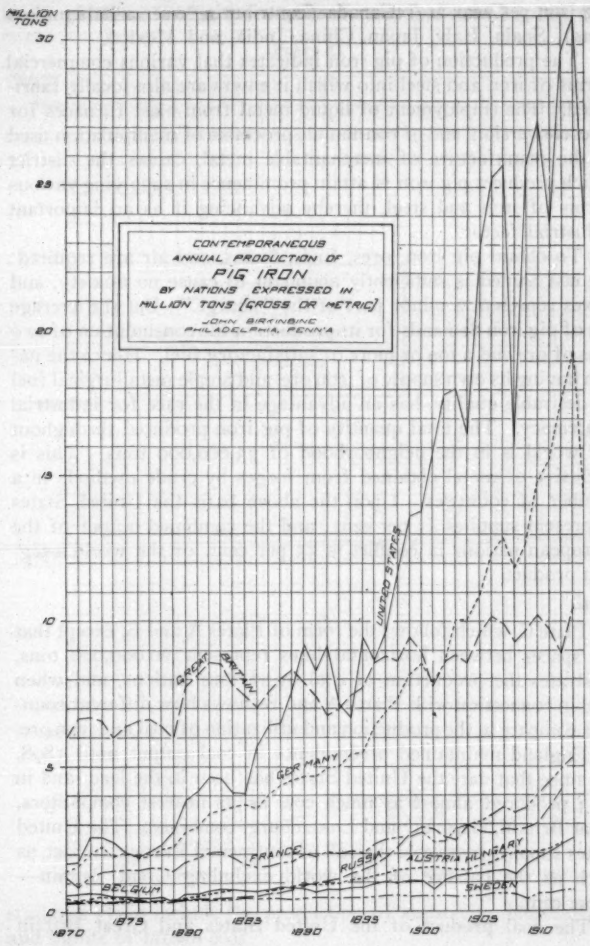
Pig Iron.

The graphic statement, Plate B, illustrates by ordinates, each space between horizontal lines representing 1,000,000 tons, the status of various countries as pig-iron producers subsequent to 1869, and indicates by "curves" the annual contribution of each nation in tons.

The diagram shows that England, which had long been preeminent in pig-iron manufacture, was outstripped by the United States in 1890, and that in 1903 Germany's product also exceeded that of Great Britain. Plate B, read in connection with Plate A, demonstrates that some important pig-iron producing countries depend to a greater or less extent upon other nations for iron ore, a feature which is later discussed.

Sweden, long celebrated for the excellence of its pig iron produced with charcoal as fuel, is included in Plate B, although its output is below, while those of all other nations shown on the diagram at present exceed 1,000,000 tons of pig iron annually. It will be noted that the maximum production of pig iron in each of the nations discussed was obtained within the past four years.

PLATE B.


MILLION TONS
30
25
20
15
10
5
0
1870
1875
1880
1885
1890
1895
1900
1905
1910
CONTEMPORANEOUS
ANNUAL PRODUCTION OF
PIG IRON
BY NATIONS EXPRESSED IN
MILLION TONS (GROSS OR METRIC)
JOHN BIRKINBINE
PHILADELPHIA, PENN'A
GREAT BRITAIN
UNITED STATES
GERMANY
FRANCE
RUSSIA
AUSTRIA HUNGARY
BELGIUM
SWEDEN

Among the countries supplying less than 1,000,000 tons of pig iron per year are: Canada (contributing over a half million tons), Spain, Italy, Japan, China, India, and Mexico.

The production of pig iron indicates that various commercial forms of iron and steel into which it enters are also locally fabricated. The employment of liquid metal from blast furnaces for steel conversion, and of continuous processes of manipulation used in the manufacture of merchantable metal, causes the district which produces pig iron to attain prominence in supplying various forms of iron and steel, thereby advancing it as an important industrial factor.

To obtain pig iron, ores, fuels, fluxes, and air are required; the last named is sufficiently abundant to cause no anxiety, and fluxes represent a minor part of the "charge." But the average ton of pig iron demands for its production the consumption of two tons of ore and a ton or more of satisfactory fuel. Hence the nation having its own supply of iron ore, and ample metallurgical fuel of desirable quality, has an advantage in the race for industrial supremacy. The total quantity of pig iron produced throughout the world is in the neighborhood of 73,000,000 tons. This is exclusive of metal obtained from forges by crude methods in a number of countries. Upon the above basis the United States at present supplies 41 per cent., and the combined output of the European nations in conflict is 55 per cent. of the world's pig-iron product.

Coal.

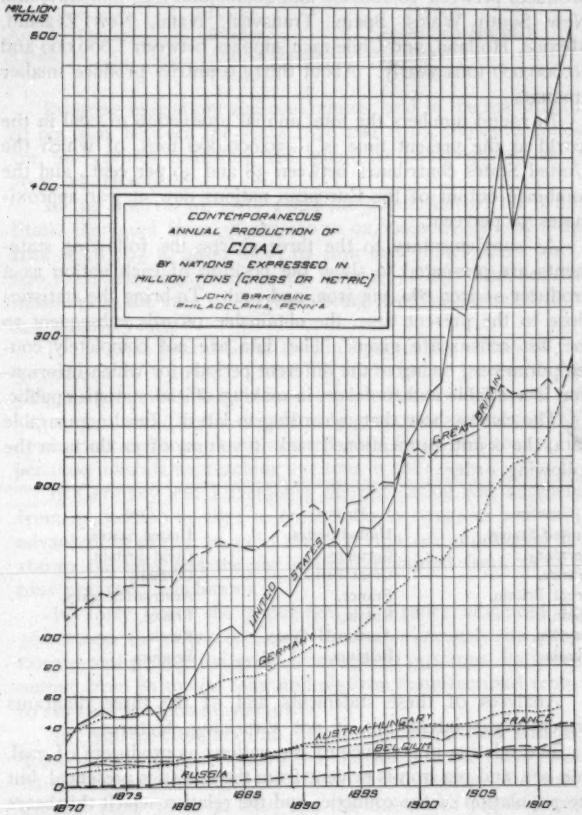
Plate C, which follows the form of Plates A and B, except that the spaces between horizontal lines represent 20,000,000 tons, illustrates the production of coal by various nations, and when read in connection with Plates A and B shows how different countries compare in the production and utilization of coal and iron ore.

England maintained preëminence in coal output until 1898, but since that date the United States has been in the lead, and in 1913 produced almost as much coal as its nearest competitors, Great Britain, Germany and Luxemburg, combined. The United States supplies more coal than all of continental Europe; in fact, as much as the balance of the world excluding Great Britain—39 per cent.

The coal product of the United States and Great Britain

averages higher grade than that of continental Europe, where large quantities of lignite or brown coal are secured, but the

PLATE C.



statistics given include the production of anthracite, bituminous, and lignite or brown coal.

In Plate C only those countries contributing 20,000,000 long or metric tons annually are indicated, but other countries mine large quantities of coal. Japan, China, India, and Canada each produces between 10,000,000 and 20,000,000 tons annually, and New South Wales, Spain, Transvaal, Natal, New Zealand, Mexico, Holland, and Chile each supplies between 1,000,000 and 10,000,000 tons yearly. About thirty countries produce smaller amounts.

In round numbers the total annual production of coal in the world at the present time is 1,250,000,000 tons, of which the United States contributes between 38 and 39 per cent., and the combined output of the European nations now at war approximates 50 per cent.

As supplementary to the three charts, the following statements are presented to show the position of each nation as a producer of iron ore, pig iron, and coal. To bring the statistics close to the present time, the obtainable records subsequent to the last census are given. The data are not completely contemporaneous, owing to the different periods for which information is available and to delays in making official statistics public.

The charts show that, according to latest official comparable data, the countries mentioned rank in volume of products in the following order:

Iron ore	Pig iron	Coal
United States,	United States,	United States,
Germany,	Germany,	Great Britain,
France,	Great Britain,	Germany,
Great Britain,	France,	Austria-Hungary,
Spain,	Russia,	France,
Sweden,	Austria-Hungary,	Russia,
Russia.	Belgium.	Belgium.

Analyses of these statements and of the three diagrams present some interesting, if not surprising, features.

The relative importance of the nations as producers of coal, iron ore, and pig iron is evident from the statistics presented, but the population of the countries and the relation which this bears to the quantities produced are of interest.

Thus, in per capita production, the nations rank:

As producers of iron ore	As producers of pig iron	As producers of coal
Sweden,	United States,	Great Britain,
United States,	Belgium,	United States,
Germany,	Germany,	Germany,
France,	Great Britain,	Belgium,
Great Britain,	France,	France,
Austria-Hungary,	Sweden,	Austria-Hungary,
Russia.	Austria-Hungary,	Japan,
	Russia.	Russia.

Progress in iron ore and coal mining, and in the manufacture of pig iron, between the years 1870 and 1910, shows as follows for the various countries, the quantities being quoted as per 1000 inhabitants:

In the interval of forty years the population of the United States increased from 38,500,000 to 92,000,000; its coal output rose from 765 to 4869 tons; its iron ores mined from 100 to 620 tons, and its pig iron made from 43 to 297 tons per 1000 inhabitants, the rate of increase being most pronounced in the last twenty years.

In the same period Great Britain's population advanced from 32,000,000 to 45,000,000, and its coal output increased from 3685 to 5994 tons, but its iron ore production decreased from 513 to 342 tons (in the decade ending 1901 to 292 tons). The amount of pig iron manufactured rose from 208 to 214 tons per 1000 inhabitants, reaching 231 tons in 1881.

In Germany and Luxemburg the population was augmented from 41,000,000 in 1871 to 66,000,000 in 1910; its coal output advanced from 922 to 3360 tons, its iron ore production from 106 to 434 tons, and the pig iron manufactured from 38 to 224 tons per 1000 inhabitants.

In forty years the population of France advanced from 36,000,000 to 39,600,000, and contemporaneously its proportionate coal production grew from 438 to 991 tons, its iron ore output from 85 to 404 tons, and pig iron manufactured from 34 to 113 tons per 1000 inhabitants.

In Austria-Hungary the increase in population was from 36,000,000 in 1870 to 49,000,000 in 1910. In the same interval its coal output was augmented from 233 to 989 tons, its iron ore product from 32 to 92 tons, and the amount of pig iron manufactured from 13 to 41 tons per 1000 inhabitants.

From 1870 to 1912 the population of Russia has risen from

85,000,000 to 171,000,000, and in that interval its coal mined advanced from 8 to 179 tons, its iron ore output from 9 to 41 tons, and its pig iron manufactured from 4 to 24 tons per 1000 inhabitants.

Belgium produces but little iron ore, but, while its population advanced from 5,000,000 in 1870 to 7,500,000 in 1910, its proportionate coal output rose from 2692 to 3222 tons, reaching 3505 tons in the year 1900. This nation is a liberal manufacturer of pig iron, of which it produced 111 tons in 1870 and 249 tons in 1910 per 1000 of population.

Sweden differs from Belgium in having but a small coal supply but an abundance of iron ore. In the forty years the population advanced from 4,000,000 to 5,500,000, its iron ore output, much of which is exported, rose from 151 to 1006 tons, and its pig-iron production using charcoal as fuel from 72 to 109 tons per 1000 inhabitants.

To illustrate the position of various nations as producers of coal, iron ore and pig iron, a series of statistical statements has been prepared covering the interval from 1870 to the present time, divided by decades. These show for each nation the total production in a decade, also the mean, maximum and minimum annual productions.

Reference has been made to the interdependence of nations, and, without attempting detailed explanation, this is epitomized in statements from latest data available of the amounts of iron ore, coal and pig iron exported and imported by various countries.

In the *United States* all iron ore produced, except about 1,000,000 tons annually exported to Canada, is smelted in the country, and in addition, in late years, from 2,000,000 to 2,600,000 tons of iron ore are imported, principally from Cuba, Sweden, and Newfoundland.

The imports of pig iron and ferro alloys in late years into the United States range from 130,000 to 237,000 tons and the exports from 60,000 to 275,000 tons, showing that the domestic pig iron is used at home.

From 12,000,000 to 22,000,000 tons of coal are annually exported from and 1,250,000 to 2,000,000 tons imported into the United States.

Germany and Luxemburg smelt their domestic iron ores, and in addition import 11,000,000 to 14,000,000 tons, principally

from Sweden, France, and Spain, and have exported about 2,500,000 tons, chiefly to Belgium and to France.

Germany annually imports 125,000 to 140,000 tons, and exports in the neighborhood of 1,000,000 tons of pig iron.

Thirty-one million to thirty-four million five hundred thousand tons of German coal are exported to Austria-Hungary, Holland, Belgium, France, Sweden, and Russia, and from 17,500,000 to 18,500,000 tons are imported into Germany.

Great Britain, in addition to its domestic iron ore supply, draws 6,000,000 to nearly 8,000,000 tons from foreign mines, two-thirds coming from Spain, although Algeria, Norway, Sweden, Tunis, Greece, and France contribute considerable quantities. No ore is exported.

Great Britain exports from 1,000,000 to 2,000,000 tons of pig iron, but the imports seldom exceed 250,000 tons.

Of its large fuel production, 65,000,000 tons of coal and about 1,000,000 tons of coke are exported to continental European, South American, and other countries. Those receiving more than 5,000,000 tons of British fuel annually are France, Italy, Germany, Sweden, and Norway.

France.—Four million to over eight million tons of French iron ore are annually exported, principally to Belgium and Germany, and from 1,000,000 to 2,000,000 tons of iron ore are imported, mostly from Germany and Spain. France exported from 100,000 to 250,000 tons of pig iron annually, while its imports of this metal are less than half these amounts.

France imports (mostly from England) about 16,000,000 tons of coal and 2,000,000 to 2,750,000 tons of coke, while its fuel exports are from 1,300,000 to 2,000,000 tons.

Russia exports little iron ore, but about 4,000,000 tons of coal and 500,000 or more tons of coke are imported.

Austria-Hungary imports annually from 500,000 to 600,000 tons of iron ore, mainly from Sweden, and exports about 100,000 tons, principally to Germany. From 100,000 to 200,000 tons of pig iron are imported and 28,000 to 60,000 tons exported.

From 9,000,000 to 12,000,000 tons of coal are imported, principally from Germany, and 8,000,000 tons, mostly lignite, are exported chiefly to Germany.

Spain is a large iron ore producer, and exports 7,000,000 to 9,000,000 tons per year, the greater portion going to Great

Britain. It produces 300,000 to 400,000 tons of pig iron, and its imports and exports are small. The domestic production of coal is augmented by importations of 2,000,000 tons annually.

Belgium mines from 125,000 to 250,000 tons of iron ore annually, but imports mostly from France, Germany, and Spain 5,000,000 to 6,000,000 tons, about 500,000 tons of which are reëxported to Germany.

Belgium fabricates practically all of its pig-iron product, and also imports about two-thirds of a million tons annually, the larger part from Germany, although Great Britain and France also furnish pig iron. It mines from 22,000,000 to 24,000,000 tons of coal, imports 6,000,000 to 7,500,000 tons, and exports about 5,000,000 tons, principally to France.

Sweden produces an abundance of high-grade iron ore, the greater part of which is exported to Germany, England, Belgium, and the United States. The pig-iron industry depends almost entirely on charcoal, about one-fourth of the production being exported.

The various nations have been discussed independently of any colonies or dependencies, for, as before stated, the pig iron made has not been followed through mills and factories. But the statements presented may indicate how intimate the association has been between nations now combating each other and seeking to cripple their adversaries in every possible manner. These may also suggest the present and prospective status of each country as a contributor to the supply of resources necessary for the world's advancement, and show how changes of boundary lines may enlarge or reduce the independent manufacturing possibilities of the nations now at war.

On preceding pages reference has been made to the necessary interchange of the raw or the manufactured materials between the countries now at conflict, and it is possible that the result of the war may greatly strengthen some or seriously cripple others of the contestants, according to the peace terms which may be agreed upon. The commercial supremacy of each nation is, to a great extent, controlled by its ability to manufacture articles of iron and steel.

The effects of such changes may extend far beyond the limits of the countries contending with each other, and the possession of natural reserves of some nations or colonies and also in the Orient may be more than a mere incident in the European War.

PRODUCTION OF IRON ORE in the Eight Principal Iron-Ore Mining Countries in the World, from 1870 to 1913, by Ten-year Periods.

UNITED STATES—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	44,645,440	4,464,544	1879	5,255,000	1876	3,734,000
1880 1889	95,089,403	9,508,940	1889	14,518,041	1880	7,120,362
1890 1899	163,989,193	16,398,919	1899	24,683,173	1893	11,587,629
1900 1909	383,932,500	38,393,250	1907	51,720,619	1900	27,553,161
1910 1913	218,022,042	54,505,510	1913	61,980,437	1911	43,876,552

GERMANY AND LUXEMBURG—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	51,160,842	5,116,084	1873	6,177,576	1870	3,839,222
1880 1889	89,499,306	8,949,931	1889	11,002,187	1880	7,238,640
1890 1899	133,313,059	13,331,306	1899	17,989,635	1891	10,657,521
1900 1909	224,434,495	22,443,450	1907	27,697,127	1901	16,570,182
1910 1913	128,284,212	32,071,053	1913	35,941,285	1910	28,729,700

GREAT BRITAIN—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	156,173,886	15,617,389	1876	16,841,584	1870	14,370,655
1880 1889	158,823,859	15,882,386	1882	18,031,957	1887	13,098,041
1890 1899	130,184,239	13,018,424	1899	14,461,330	1893	11,203,476
1900 1909	142,877,457	14,287,746	1907	15,731,604	1901	12,275,198
1910 1913	60,533,158	15,133,290	1913	15,997,328	1912	13,790,391

FRANCE—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	25,715,612	2,571,561	1872	3,081,026	1871	2,099,706
1880 1889	28,743,748	2,874,375	1882	3,467,251	1886	2,285,648
1890 1899	40,088,780	4,008,878	1899	4,985,702	1890	3,471,718
1900 1909	76,317,045	7,631,705	1909	11,890,000	1902	5,003,782
1910 1912	49,410,078	16,470,026	1912	18,800,000	1910	14,605,542

PRODUCTION OF IRON ORE in the Eight Principal Iron-Ore Mining Countries in the World, from 1870 to 1913, by Ten-year Periods.—Continued.

SPAIN—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 to 1879	9,419,302	941,930	1874	423,401	1877	1,578,150
1880 to 1889	46,444,883	4,644,488	1887	6,796,266	1881	3,502,681
1890 to 1899	63,292,106	6,329,211	1899	9,397,733	1892	5,041,317
1900 to 1909	87,235,290	8,723,529	1907	9,896,178	1902	7,904,555
1910 to 1911	17,440,486	8,720,243	1911	8,773,691	1910	8,666,795

RUSSIAN EMPIRE—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 to 1879	9,166,008	916,601	1875	1,056,545	1871	794,779
1880 to 1889	11,692,556	1,169,256	1889	1,646,840	1883	998,393
1890 to 1899	30,468,011	3,046,801	1899	5,788,709	1890	1,802,165
1900 to 1909	50,621,536	5,062,154	1900	6,122,270	1902	4,004,007
1910 to 1911	12,750,218	6,375,109	1911	6,985,039	1910	5,765,179

SWEDEN—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 to 1879	7,466,982	746,698	1874	926,825	1870	630,739
1880 to 1889	8,883,492	888,349	1889	985,904	1880	775,344
1890 to 1899	17,402,164	1,740,216	1899	2,435,200	1890	941,241
1900 to 1909	38,011,618	3,801,162	1908	4,713,160	1900	2,609,500
1910 to 1913	25,886,414	6,471,604	1913	7,479,393	1910	5,552,678

AUSTRIA-HUNGARY—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1871 to 1879	10,246,331	1,138,481	1873	1,588,058	1877	884,260
1880 to 1889	14,632,594	1,463,259	1889	1,780,772	1881	1,084,443
1890 to 1899	25,162,976	2,516,298	1899	3,293,004	1892	1,913,831
1900 to 1909	37,511,679	3,751,168	1908	4,568,814	1903	3,155,116
1910 to 1911	9,245,998	4,622,999	1911	4,712,666	1910	4,533,332

PRODUCTION OF PIG IRON in the Eight Principal Pig-iron Producing Countries in the World, from 1870 to 1914, by Ten-year Periods.

UNITED STATES—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 } .. 1879 }	21,885,266	2,188,527	1879	2,741,853	1870	1,665,179
1880 } .. 1889 }	51,534,529	5,153,453	1889	7,603,642	1880	3,835,191
1890 } .. 1899 }	93,538,215	9,353,822	1899	13,620,703	1894	6,657,388
1900 } .. 1909 }	197,807,609	19,780,761	1909	25,795,471	1900	13,789,242
1910 } .. 1914 }	134,978,776	26,995,755	1913	30,966,301	1914	23,332,244

GERMANY AND LUXEMBURG—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 } .. 1879 }	19,272,726	1,927,273	1873	2,240,575	1870	1,391,124
1880 } .. 1889 }	36,195,906	3,619,591	1889	4,524,558	1880	2,729,038
1890 } .. 1899 }	58,777,609	5,877,761	1899	8,143,132	1891	4,641,217
1900 } .. 1909 }	105,500,005	10,550,001	1907	12,875,159	1901	7,880,087
1910 } .. 1914 }	81,683,742	16,336,748	1913	19,309,172	1914	14,389,547

GREAT BRITAIN—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 } .. 1879 }	63,796,993	6,379,699	1872	6,741,929	1870	5,963,515
1880 } .. 1889 }	79,127,923	7,912,792	1882	8,586,680	1886	7,009,754
1890 } .. 1899 }	79,614,624	7,961,462	1899	9,421,435	1892	6,709,255
1900 } .. 1909 }	91,251,065	9,125,107	1906	10,149,388	1901	7,761,832
1910 } .. 1913 }	39,306,601	9,826,650	1913	10,481,917	1912	8,889,124

FRANCE—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 } .. 1879 }	13,364,987	1,336,499	1878	1,521,274	1871	859,641
1880 } .. 1889 }	17,723,834	1,772,383	1883	2,069,430	1886	1,516,574
1890 } .. 1899 }	21,919,062	2,191,906	1899	2,567,388	1891	1,897,387
1900 } .. 1909 }	30,278,382	3,027,838	1907	3,590,235	1901	2,388,823
1910 } .. 1913 }	18,758,948	4,689,737	1913	5,311,316	1910	4,038,297

PRODUCTION OF PIG IRON in the Eight Principal Pig-iron Producing Countries in the World, from 1870 to 1914, by Ten-year Periods.—Continued.

RUSSIA—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870–1879	3,805,983	380,598	1879	420,660	1871	339,513
1880–1889	5,278,717	527,872	1889	733,720	1880	427,696
1890–1899	15,113,846	1,511,385	1899	2,677,120	1890	905,460
1900–1901	27,634,376	2,763,438	1904	2,962,283	1903	2,449,701
1910–1912	10,830,846	3,610,282	1912	4,197,635	1910	3,040,047

AUSTRIA-HUNGARY—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870–1879	4,423,447	442,345	1873	534,508	1877	387,630
1880–1889	6,838,158	683,816	1889	855,822	1880	464,234
1890–1899	11,431,258	1,143,126	1899	1,467,664	1891	921,846
1900–1909	16,119,729	1,611,973	1909	1,995,511	1904	1,375,865
1910–1912	6,545,212	2,181,737	1912	2,372,660	1910	2,060,975

BELGIUM—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870–1879	5,379,203	537,920	1872	655,565	1879	389,330
1880–1889	7,323,421	732,342	1889	832,226	1880	608,084
1890–1899	8,631,404	863,140	1899	1,036,185	1891	684,126
1900–1909	12,335,766	1,233,577	1909	1,616,370	1901	764,180
1910–1913	8,726,830	2,181,708	1913	2,527,070	1910	1,852,090

SWEDEN—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870–1879	3,343,027	334,303	1876	352,467	1871	298,761
1880–1889	4,329,398	432,940	1885	464,737	1882	398,945
1890–1899	4,873,948	487,395	1897	538,197	1893	453,421
1900–1909	5,401,295	540,130	1907	615,778	1909	444,764
1910–1913	2,668,404	667,101	1913	730,257	1910	603,939

PRODUCTION OF COAL in the Eight Principal Coal-Mining Countries in the World, from 1870 to 1913, by Ten-year Periods.

UNITED STATES—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870–1879	476,566,017	47,656,602	1879	60,808,749	1870	29,496,054
1880–1889	1,019,753,264	101,975,326	1888	132,701,827	1880	63,822,830
1890–1899	1,712,331,738	171,233,174	1899	226,554,635	1890	140,866,931
1900–1909	3,337,185,589	333,718,559	1907	428,895,914	1900	240,789,310
1910–1913	1,877,082,366	469,270,592	1913	508,971,540	1911	443,054,614

GREAT BRITAIN—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870–1879	1,274,494,850	127,449,485	1877	134,179,968	1870	110,431,192
1880–1889	1,607,990,447	160,799,045	1889	176,916,724	1880	146,969,409
1890–1899	1,910,785,455	191,078,546	1899	220,094,781	1893	164,325,795
1900–1909	2,414,416,661	241,441,666	1907	267,830,962	1901	219,046,945
1910–1913	1,084,171,738	271,042,935	1913	287,430,473	1912	260,416,338

GERMANY—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870–1879	456,561,932	45,656,193	1879	53,470,716	1870	34,003,004
1880–1889	719,117,229	71,911,723	1889	84,973,230	1880	59,118,035
1890–1899	1,073,735,837	107,373,584	1899	135,824,427	1890	89,051,527
1900–1909	1,791,128,249	179,112,825	1909	217,445,656	1900	149,788,256
1910–1912	711,706,424	237,235,475	1912	255,810,094	1910	222,375,076

FRANCE—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870–1879	161,713,709	16,171,371	1873	17,479,341	1871	13,258,920
1880–1889	208,703,065	20,870,307	1889	24,303,509	1881	19,361,564
1890–1899	286,581,124	28,658,112	1899	32,863,000	1893	25,650,981
1900–1909	346,903,640	34,690,364	1909	37,840,086	1902	29,997,470
1910–1913	159,716,914	39,929,229	1912	41,145,178	1910	38,349,942

PRODUCTION OF COAL in the Eight Principal Coal-Mining Countries in the World, from 1870 to 1913 by 10-year periods.

AUSTRIA-HUNGARY—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	121,822,412	12,182,241	1879	14,891,024	1870	8,355,944
1880 1889	202,430,110	20,243,011	1889	25,328,417	1880	16,128,718
1890 1899	325,647,572	32,564,757	1899	38,739,000	1890	27,504,032
1900 1909	439,719,257	43,971,926	1908	49,626,184	1900	39,502,301
1910 1912	151,031,218	50,343,739	1912	52,521,776	1910	48,649,768

RUSSIA—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	15,555,667	1,555,567	1879	2,874,790	1870	696,673
1880 1889	43,237,790	4,323,779	1889	6,213,869	1880	3,286,534
1890 1899	91,966,854	9,196,685	1899	14,311,200	1890	6,085,080
1900 1909	204,227,251	20,422,725	1909	26,075,086	1900	16,135,600
1910 1912	83,551,747	27,850,582	1912	30,646,163	1910	24,898,345

BELGIUM—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	146,893,125	14,689,313	1873	15,778,401	1877	13,669,077
1880 1889	179,771,122	17,977,112	1889	19,869,980	1881	16,873,951
1890 1899	206,800,233	20,680,023	1898	22,075,093	1893	19,410,519
1900 1909	231,237,587	23,123,759	1907	23,705,190	1905	21,775,280
1910 1912	69,942,240	23,314,060	1910	23,916,560	1912	22,972,140

JAPAN—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1881 1889	12,808,235	1,423,136	1889	2,388,614	1881	925,198
1890 1899	45,721,857	4,572,186	1898	6,761,301	1890	2,608,284
1900 1909	115,283,197	11,528,320	1909	14,973,617	1900	7,429,457
1910 1912	52,953,789	17,651,263	1912	19,639,755	1910	15,681,324

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE SPECIFIC HEAT AND HEAT OF FUSION OF ICE.

By H. C. Dickinson and N. S. Osborne.

RESULTS of previous determinations of the specific heat of ice by certain observers have indicated a rapid increase in the specific heat on approaching the melting-point; whereas A. W. Smith† has found the heat capacity of ice to be practically constant up to temperatures very close to zero, provided great care and refinement are used to insure the purity of the ice, and that sensible increase in the apparent heat capacity with ice samples of only ordinary purity are accounted for by the assumption of incipient fusion caused by the lowering of the melting-point by the dissolved impurities.

The present investigation has been undertaken with the object of securing further evidence as to the thermal behavior of ice at temperatures near the freezing-point, and of obtaining reliable data for the construction of tables of total heat of ice and water in the range of temperature with which refrigerating engineers are concerned.

The measurements were made by means of a calorimeter of aneroid type (*i.e.*, without stirred liquid as calorimetric medium), which is described in detail in a separate paper.

Briefly described, the tin-lined metal cell containing the specimen is enclosed within a shell of copper, the copper acting as the calorimetric medium for transmission and distribution of heat electrically developed in a coil built into the shell. The calorimeter is surrounded by air and enclosed in a metal jacket which is surrounded by a stirred liquid bath, the temperature of which can be controlled within a few thousandths of a degree at any temperature between $-55°$ and $+40°$ C. Measured amounts of heat are supplied to the calorimeter electrically by means of the built-in heating coil. The calorimeter temperature is measured by means of a platinum resistance thermometer also

* Communicated by the Bureau.

† *Physical Review*, 17 (1903), p. 193.

built into the shell. Differences in temperature between the calorimeter and jacket surfaces are measured by means of multiple thermocouples distributed on the surfaces. During an experiment thermal leakage is minimized by keeping the temperature of the jacket nearly equal to the changing temperature of the calorimeter.

The samples used were from 400 to 470 grammes each. Three samples were of redistilled water of fairly high purity, while a fourth, which was distilled directly into the container, appeared, from the experimental results, to have a much higher degree of purity.

In the determinations of specific heat it is found that over the range of temperature covered by the experiments (*i.e.*, $-40°$ to $-0.05°$ C.) the specific heat S, in 20° calories at any temperature θ, of the four ice samples is represented within the limit of experimental error by the equation:

$$S = 0.5057 + 0.001863\theta - 79.75\,\frac{l}{\theta^2}$$

in which the constant l is assumed to represent the the initial freezing-point of the specimen and has the following values:

Sample	l
1	− 0.00125
2	.00120
3	.00095
4	.00005

From the fact that the term which represents the departure of the specific heat from a linear function of the temperature is found to depend on the purity, being less the purer the ice, it is concluded that the specific heat of pure ice in 20° calories may be closely represented by the equation:

$$S = 0.5057 + 0.001863\theta$$

Determinations of the heat of fusion made upon three of the samples used for the specific heat determinations gave the following values:

Sample number	Heat of fusion, Cal 20/0
1	79.68
2	79.85
4	79.75
Mean	79.76

The results of a previous investigation at the Bureau of Standards using very different methods to determine the heat of fusion of ice give, when corrected for the newly-found value for specific heat, a mean value of 79.74 20° calories per gramme.

The mean for the two investigations is 79.75 20° calories per gramme.

For the use of engineers a table of total heats of ice and water is given expressed in B. T. U.'s per pound at temperatures from −20° F. to +100° F.

TABLE 12.

Table of Total Heat of Ice and Water.

Temperature of ice t deg. F.	Difference in total heat per pound from ice at t to Ice at 32° $H_{32}-H_t$ B.T.U./lb.	Water at 32° $h_{32}-H_t$ B.T.U./lb.	Temperature of water t' deg. F.	Difference in total heat per pound from water at 32° to water at t' $h_{t'}-h_{32}$ B.T.U./lb.
−20	23.8	167.2	+32	0.0
−18	22.9	166.3	34	2.0
−16	22.1	165.5	36	4.0
−14	21.3	164.7	38	6.0
−12	20.4	163.8	40	8.1
−10	19.6	163.0	42	10.1
− 8	18.7	162.1	44	12.1
− 6	17.9	161.3	46	14.1
− 4	17.0	160.4	48	16.1
− 2	16.1	159.5	50	18.1
0	15.2	158.6	52	20.1
+2	14.3	157.7	54	22.1
4	13.4	156.8	56	24.1
6	12.5	155.9	58	26.1
8	11.6	155.0	60	28.1
10	10.7	154.1	62	30.1
12	9.7	153.1	64	32.1
14	8.8	152.2	66	34.1
16	7.8	151.2	68	36.1
18	6.9	150.3	70	38.1
20	5.9	149.3	72	40.1
22	5.0	148.4	74	42.1
24	4.0	147.4	76	44.1
26	3.0	146.4	78	46.1
28	2.0	145.4	80	48.1
30	1.0	144.4	82	50.1
32	0.0	143.4	84	52.1
			86	54.1
			88	56.1
			90	58.0
			95	63.0
			100	68.0

AN ANEROID CALORIMETER.

By H. C. Dickinson and N. S. Osborne.

THE term "aneroid calorimeter" is applied to a type of calorimeter in which equalization of temperature is secured by means of the thermal conductivity of copper instead of by the convection of a stirred liquid. The calorimeter described, which consists of a thick-walled cylindrical vessel of copper in the walls of which are embedded a coil of resistance wire to supply heat electrically, and a platinum resistance coil for use as a thermometer, has been found useful over a wide range of temperatures and is applicable to a variety of problems.

For use at low temperatures the calorimeter is mounted in a jacket surrounded by a bath of gasoline, the temperature of which can be controlled thermostatically to within a few thousandths of a degree at any temperature between $-55°$ and $+40°$ C. or can be changed rapidly in order to keep it the same as that of the calorimeter when heat is being supplied to the latter.

Differences in temperature between the surface of the calorimeter and that of the jacket are measured by means of multiple thermocouples which have ten junctions distributed over the surface of each, thus making it possible to apply accurate corrections for thermal leakage between calorimeter and jacket even when the temperatures of both are changing rapidly.

The platinum resistance coil (for use as a thermometer) embedded in the calorimeter shows slight irregularities in its behavior, probably due to the difference in expansion between the platinum and the copper which surrounds it. Uncertainties on this account, while in general negligible, can be avoided by measuring the temperature of the outer bath with a standard resistance thermometer, using the thermocouples to measure the small difference, usually not more than a few thousandths of a degree, between the calorimeter and the jacket. The thermometer could probably be improved by changing the construction.

Results of a series of experiments give the constants of the resistance thermometer and the heat capacity of the calorimeter, including a tin-lined cell for use in determining the specific heat of ice and water and the latent heat of fusion of ice.

A series of check experiments on the specific heat of water shows the order of reproducibility of results which can be obtained with this calorimeter to be 1 part in 2000. Measurements

made at temperatures between 0° and 40° C. gave results which agree to within the limits of experimental accuracy with the unpublished results of a long series of experiments made in the usual form of stirred water calorimeter. The results are also in satisfactory agreement with the most probable values deducible from the data of the most careful investigations published by other observers.

A STUDY OF THE ATTERBERG PLASTICITY METHOD.*

Atterberg evaluates the plasticity of a clay in accordance with the range of water content within which it can be considered plastic. The plasticity value is expressed by a number obtained by subtracting the water content of the clay at the lower plasticity limit from the water content limit. The work of this investigator on Swedish clays is described and the results critically reviewed. The method was tried on twenty American clays and the results compared with evaluations based on per cent. water of plasticity, per cent. shrinkage, and per cent. water absorbed by the clay powders while in an atmosphere of high humidity. It was brought out that the Atterberg method does not give results which check observations made from actual experience with the clays, principally because it does not account for a sufficient number of factors. A revised adaptation of the Atterberg method is suggested in which the plasticity number is coördinated with the amount of water required to develop the best working properties of the clays. This scheme grouped the clays satisfactorily into those varieties which are sticky and would give trouble in working in a stiff-clay machine, and those which are non-sticky and admit of ready working.

CHARACTERISTICS OF RADIATION PYROMETERS.†

By George K. Burgess and Paul D. Foote.

[Abstract]

In the complete paper there have been given an account of the principles which form the basis for the operation of total radiation pyrometers, descriptions in some detail of representa-

* Technologic Papers of the Bureau of Standards, No. 46.

† To appear as a Scientific Paper of Bureau of Standards.

tive types of this instrument, together with the results of an experimental study of their calibration and behavior under various conditions of use and as modified by changing the several factors which may influence the readings of such pyrometers. A considerable portion of the text is devoted to the examination of the sources of error and their elimination or correction.

In all there were carefully examined some twenty instruments, including all the ordinary types commonly met with in practice, such as the four due to Féry, and the Foster, Thwing, and Brown pyrometers.

Although this investigation, which is largely made up of instrumental details, does not readily lend itself to a brief summary, yet the following conclusions of a general nature may be mentioned.

The Stefan-Boltzmann law $E = a\ (T^4 - T^4_o)$ is not in general, except by accident, obeyed in its exactness by any of the pyrometers examined. The similar equation $E = a\ T^4.\ T^{b-4}$, in which b is slightly different from 4 (usually neglecting the T_o term), is, however, obeyed with sufficient exactness by all total radiation pyrometers.

The main factors influencing the value of the exponent b are the geometry and mechanical construction of the instrument; the value of b for 20 thermoelectric pyrometers ranged from about 3.5 to 4.5. The same instrument of the Féry type may have a different exponent, according to its use with or without the sectored diaphragm for increasing the temperature range.

In general, a radiation pyrometer behaves not as a "black" or total receiver of energy, but as a "gray" receiver for the ordinary range of temperatures. For the Féry pyrometer with a gold mirror, for example, the effect of selective reflection of the gold mirror does not become practically appreciable until above 2500° C., but may cause an error of 500° C. at the temperature of the sun.

The auxiliary apparatus, galvanometer or potentiometer, and recording devices, can be constructed so that their errors will be practically negligible. For the work of the highest accuracy the potentiometric method of measurement is to be preferred with thermoelectric radiation pyrometers.

The principal errors to which the several types of radiation pyrometers are subject are shown to lie in the design and mechani-

cal construction of these instruments, and certain of these inherent errors, such as lag or slowness in reaching an equilibrium reading, require, for satisfactory results, that the pyrometer be calibrated and used under similar conditions of time of exposure, distance from and aperture of source. Wide variations in the lag effect exist among apparently similar instruments, ranging from a few seconds to an hour or more. These and other errors of appreciable magnitude, such as stray reflection, convection currents, intervening atmosphere, size of source, tarnishing of receiving mirror, etc., are discussed at length in the text.

It is shown that errors greater than 100° C. may readily be caused by dirt on or oxidation of mirror.

The magnitude of errors due to varying the focusing distance may amount to several hundred degrees if suitable precautions are not taken.

A convenient method for the rapid comparison of different types of pyrometer, and for determining the effects of size of aperture and focusing distance, was devised, consisting of a wide nickel (oxide) strip heated electrically, a series of circular, water-cooled diaphragms, and an optical bench.

The methods in use at this Bureau for the calibration of radiation pyrometers by means of especially designed experimental "black bodies" are described in detail and methods of extrapolation outlined, as well as methods of use of radiation pyrometers, including methods of obtaining approximately correct temperatures for the case in which a source of insufficient size is sighted upon.

Finally, there is considered the application of the radiation pyrometer to the determination of the total emissivity of non-black substances and to the measurement of temperatures.

Reciprocal Action of Cerium and Hydrogen. I. I. Joukoff. (*J. Russ. Phys.-Chem. Soc.*, xlv, 2073; *Bull. Soc. Chem.*, xvi, 531.)—Cerium, when heated in an atmosphere of hydrogen, rapidly absorbed the gas at about 350° C. Between 450° and 510° C. the dissociation pressure was about 1 mm. so long as the proportion of hydrogen did not exceed that corresponding to CeH_2; beyond this the dissociation pressure increased with the hydrogen concentration. It is concluded that the hydride CeH_2 is formed, and that this hydride is capable of dissolving hydrogen.

Electric Transmission of Vision. G. RIGNOUX. (*Comptes Rendus*, clix, 301.)—In the transmitting apparatus a number of selenium cells are employed—as many, in fact, as the number of points to be transmitted. The currents furnished by the selenium cells being too small to be used with an apparatus for the magnetic rotation of the plane of polarization of a beam of light, each selenium cell is connected to a relay. Similar terminals of these relays are connected to the sectors of a commutator, so that each is connected in turn through a battery to the coil of the polarization apparatus. Along the axis of the coil there is a tube of carbon tetrachloride, through which a beam of polarized light is sent. A nicol at the end of the tube transmits more or less light, according to the amount of rotation of the plane of polarization of the light in its passage through the tube. An arrangement of lenses and rotating mirrors serves to direct the emergent beam to a point on a screen corresponding to the particular selenium cell which is at any particular instant in use. Thus a series of points, corresponding in brightness or darkness to points on the object to be viewed at a distance, is obtained on the screen, and if these succeed one another with sufficient rapidity the persistence of vision allows the whole of the object to be seen at once. A rough apparatus on these lines has been made, and letters or other objects presented to the transmitter have been seen projected on the screen of the receiving apparatus. Various points in which the apparatus may be improved are noted. The disadvantage of the relays is that they will give no gradation; they either operate or do not operate. It is thought that by utilizing a small type of dynamo a continuous gradation of current may be obtained, corresponding to the luminous intensity received by each cell.

New Method for Fumigating Imported Seed.—A satisfactory method for destroying injurious insects in imported seed without affecting the value of the seed has been used by the United States Department of Agriculture, and is described in a new bulletin (No. 186), entitled "A Method of Fumigating Seed."

In the new method the infested seed is placed in a chamber in which a partial vacuum has been created. The chamber is then filled with a very deadly gas—hydrocyanic acid—which penetrates more effectively into the seed because of the previously-created vacuum. It has been found that a considerably shorter exposure was necessary in using this method of fumigation than in the usual method. The bulletin describes the experiment completely, giving details and illustrations of the chamber used in the experiment.

Hydrocyanic acid is, of course, a most dangerous poison and should not be handled by any except those who are thoroughly familiar with it. Another gas—carbon bisulphide—is to be used by the department in a similar experiment, the results of which will be announced later.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, March 17, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 17, 1915.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 6.

The paper of the evening, on "High Temperature Investigations," was read by Dr. Edwin F. Northrup, of the Palmer Physical Laboratory, Princeton University. A summary was presented of the results of investigations by the speaker in the measurement of high temperatures. New furnaces for the production of high temperature were shown in operation for the first time.

A high temperature pyrometer and resistometer, recently devised, was also exhibited and described. The problems of electrical conductivity at high temperatures and the electrical conduction of metals in liquid and vapor states were given consideration.

The subject was illustrated by lantern slides and numerous experiments. After a discussion by Drs. Richards and Goldsmith, Messrs. Snook, Fulweiler, Spencer, and others, the thanks of the meeting were extended to Dr. Northrup.

Adjourned.

R. B. OWENS,
Secretary.

(Proceedings of the Joint Meeting held Friday, March 19, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 19, 1915.

A joint meeting of the Institute and the Philadelphia Section of the Illuminating Engineering Society was held in the Hall of the Institute on Friday evening, March 19, 1915, at 8 o'clock.

Dr. George A. Hoadley and Mr. H. A. Hornor presided jointly.

A paper on "Method of Securing Uniformity of Readings on the Flicker Photometer with Different Observers," by Herbert E. Ives and E. F. Kingsbury, was presented by Dr. Ives.

Professor John Hammond Smith, of the University of Pittsburgh, read a communication on "Photo-Sculpturing." The papers were illustrated by lantern slides and experiments.

A discussion ensued in which Dr. Hoadley, Messrs. Hornor, Bond, Rowland, and others took part.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 3, 1915.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 3, 1915.

MR. GEORGE R. HENDERSON *in the Chair.*

The following report was presented for final action:

No. 2586.—Dobbins's Daylight Rods. Edward Longstreth Medal of Merit to Edward J. Dobbins, of London, England, adopted.

R. B. OWENS,
Secretary.

AWARD OF THE EDWARD LONGSTRETH MEDAL OF MERIT.

Mr. Edward J. Dobbins, of London, England, has been awarded the Edward Longstreth Medal of Merit for his Daylight Rods. These rods have been designed for use in increasing the daylight illumination of interior spaces, for which purpose they replace prismatic glass glazed into windows, canopies, or mirrors. Each rod is of clear glass and is cylindrical, with a longitudinal groove one side of which is flat and the other formed of lenses of small curvature. A number of the rods are mounted in a frame fastened outside and flush with the window frame. When mounted, the rods have their axes parallel, and by a special arrangement all can be revolved together and set to any desired angle. The same form of rod can be used in all conditions of lighting, and the rods can be easily cleaned and replaced if broken.

SECTIONS.

Section of Photography and Microscopy.—A joint meeting of the Section and of the Photographic Society of Philadelphia was held in the Hall of the Institute on Thursday, February 25, 1915, at 8 P.M.

Dr. Henry Leffmann presided.

Mr. Henry Hess, M.E., of Philadelphia, Pa., delivered a lecture, entitled "Recent Progress in Making Photographs in Color." By means of lantern slides the speaker explained the laws and phenomena underlying color photographic processes. He gave several examples of the results obtained by means of those particular processes which require very little skill.

After a brief discussion the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 4, 1915, at 8 P.M.

Mr. George R. Henderson, president of the Section, occupied the chair.

Mr. Carleton E. Davis, Chief, Bureau of Water, City Hall, Philadelphia,

Pa., delivered a lecture, entitled "Hydraulic Works of the Panama Canal." The speaker dealt more particularly with the provisions of water works and sewers in the Canal Zone and in the cities of Panama and Colon. In this connection he described the draining and ditching of certain areas and the construction of modern hydraulic works in others to render the entire zone free from insects and the workers on the canal immune from malaria and yellow fever. He stated that this preliminary work was of such significance as to justify giving it a permanent place in the records of the building of the canal.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, March 10, 1915.)

RESIDENT.

MR. RONALD G. COOLBAUGH, 32 North Front Street, Camden, N. J.

NON-RESIDENT.

MR. JOHN H. BARR, 293 Broadway, New York, N. Y.
MR. ELBRIDGE L. GIBBS, 1928 Oak Street, Jacksonville, Fla.
MR. NATHAN E. LEWIS, 85 Liberty Street, New York, N. Y.
MR. EUGENE L. MAINES, 195 Exchange Street, Rochester, N. Y.
MR. ORVILLE CAMPBELL SKINNER, "Open Hearth," Burnham, Pa.

CHANGES OF ADDRESS.

MR. CHARLES E. BENNETT, 461 Gas and Electric Building, Atlanta, Ga.
MR. WILLIAM B. HALSEY, Locust Avenue and Stewart Street, St. Albans, Long Island, N. Y.
MR. JOHN W. HORNSEY, Summit, N. J.
MR. JOHN S. ROOKE, 2002 North 29th Street, Philadelphia, Pa.

NECROLOGY.

William O. Griggs was born in 1845 and died on February 21, 1915. He was a graduate of the Jefferson and Hahnemann Medical Colleges.

Dr. Griggs became a life member of the Institute in November, 1889, and in 1903 was elected to membership in its Committee on Science and the Arts. He served as chairman of this committee during 1907, and for a number of years was very active, taking part in many investigations.

He was greatly interested in firearms, and his extensive collection was recently deposited in the armory of the Second Regiment, National Guard of Pennsylvania, where it will become a permanent memorial.

LIBRARY NOTES.

PURCHASES.

ABEGG, R., and AUERBACH, F., ed.—Handbuch der anorganischen Chemie. 6 volumes.: vol. 2, parts 1 and 2; vol. 3, parts 1 to 3; vol. 4, part 2. 1908–1913.

COOPER, MADISON.—Practical Cold Storage. 1914.

COSGROVE, J. J.—Sanitary Refrigeration and Ice Making. 1914.

Engineering Index.—31st Annual. 1914.

FORTIER, SAMUEL.—Use of Water in Irrigation. 1915.

GALILEI, GALILEO.—Dialogues Concerning Two New Sciences. 1914.

HALSEY, F. A.—Methods of Machine Shop Work. 1914.

LUHR, OTTO.—Mechanical and Refrigerating Engineer's Handy Book. 1913.

LYMAN, THEODORE.—Spectroscopy of the Extreme Ultra-violet. 1914.

MATTHEWS, J. M.—The Textile Fibres. 1913.

Photograms of the Year. 1914.

RICHMOND, HENRY DROOP.—Dairy Chemistry. 1914.

ROSENHAIN, WALTER.—Introduction to the Study of Physical Metallurgy. 1914.

SMITH, C. W.—Construction of Masonry Dams. 1915.

SODDY, F.—Chemistry of the Radio Elements. 1915.

TREADWELL, F. P., and HALL, W. T.—Analytical Chemistry, vol. 1, Qualitative; vol. 2, Quantitative. 1914.

GIFTS.

American Metal Company, Ltd., Comparative Statistics of Lead, Copper, Spelter, Tin, Aluminium, Quicksilver, and Silver. Frankfort-on-the-Main, 1914. (From the Company.)

American Society of Mechanical Engineers, Year Book, 1915. New York, no date. (From the Society.)

Barringer, D. M., Meteor Crater in Northern Central Arizona. No place, no date. (From the Author.)

British Board of Trade, Seventeenth Abstract of Labour Statistics. London, 1915. (From the Board of Trade.)

Buck & Hickman, Ltd., Catalogue of Lathes. London, no date. (From the Company.)

Canada Department of Mines, The Physical Properties of The Metal Cobalt, Part 2; Economic Minerals and Mining Industries of Canada. Ottawa, 1914. (From the Department.)

Carnegie Institution of Washington, Year Book, 1914. Washington, 1915. (From the Institution.)

Chain Belt Company, Catalogue No. 56 of Malleable Iron and Steel Chain Belts. Milwaukee, no date. (From the Company.)

Clark University, Register and Twenty-seventh Official Announcement. Worcester, 1915. (From the University.)

Colorado Bureau of Mines, Thirteenth Biennial Report. Denver, 1914. (From the Bureau.)

Crouse-Hinds Company, Condulet Catalogue No. 1000. Syracuse, 1914. (From the Company.)

Dixon, Joseph, Crucible Company, Graphite. Jersey City, 1914. (From the Company.)

Finlande l'Administration generale de l'industrie, Meddelanden 61st part, Suomen Teollisuushallituksen Tiedonantoja. Helsingissa, 1914. (From the Patent Office of Finland.)

Glidden Varnish Company, Catalogue of Machinery Finishes. Cleveland, no date. (From the Company.)

Institution of Civil Engineers, Proceedings. Westminster, 1914. (From the Institution.)

Institution of Mining and Metallurgy, Transactions. London, 1914. (From the Institution.)

Jenkins Brothers, Catalogue No. 20 of Valves, Packing and other Mechanical Rubber Goods. No place, no date. (From the Company.)

Kungl. Vitterhets Historie och Antikvitets Akademien, Antikvarisk Tidskrift. for Sverige. Stockholm, no date. (From the Academy.)

Leland Stanford Junior University, An Introduction to the Study of the Endocrine Glands and Internal Secretions. Stanford University, 1914. (From the Library of the University.)

Massachusetts Institute of Technology, Reports of President and Treasurer. Boston, 1915. (From the Institute.)

Massachusetts State Board of Health, Forty-fifth Annual Report, 1913. Boston, 1914. (From the Board of Health.)

Museu Nacional do Rio de Janeiro, Archivos, vol. xvi. Rio de Janeiro, 1911. (From the Museum.)

New Orleans Board of Health, Biennial Report, 1912–1913. New Orleans, no date. (From the Board of Health.)

New York Public Library, January Bulletin. New York, 1915. (From the Library.)

North Western Expanded Metal Company, Designing Data for Reinforced Concrete. Chicago, 1914. (From the Company.)

Nova Scotia Department of Public Works and Mines, Annual Report, 1914. Halifax, 1915. (From the Department.)

Pelton Water Wheel Company, Catalogue of Turbine and Tangential Water Wheels. San Francisco, 1914. (From the Company.)

Pennsylvania Commission of Soldiers' Orphan Schools, Annual Report. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Commissioner of Health, Sixth Annual Report, 1911, parts 1 and 2. Harrisburg, 1913. (From the State Librarian.)

Pennsylvania Department of Labor and Industry, Commissioner's Report, part 1, 1913. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Railroad Company, The Record of Transportation Lines, 1914. Philadelphia, 1915. (From the Company.)

Pennsylvania State Highway Department, Report, 1913–1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Superintendent of Public Instruction, Report. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Topographic and Geologic Survey, Report No. 9. Harrisburg, 1913. (From the Survey.)
Pennsylvania Water Supply Commission, Annual Report, 1913. Harrisburg, 1914. (From the State Librarian.)
Polytechnic Institute of Brooklyn, Catalogue of The College of Engineering, 1915–1916. Brooklyn, no date. (From the Institute.)
Princeton University, Catalogue. Princeton, 1914. (From the University.)
South Dakota Railroad Commission, Report, 1914. Pierre, no date. (From the Commission.)
St. Louis University, Bulletin. St. Louis, 1915. (From the University.)
St. Louis Malleable Casting Company, Catalogue No. 400 of Overhead Pole and Line Hardware. St. Louis, 1915. (From the Company.)
Tennessee Railroad Commission, Report. Jackson, 1914. (From the Commission.)
United States Brewers' Association, Year Book. New York, 1914. (From the Association.)
United States Cast Iron Pipe and Foundry Company, General Catalogue of Cast Iron Pipe. Burlington, 1914. (From the Company.)
University of Pennsylvania, Catalogue, 1914–1915. Philadelphia, 1915. (From the University.)
University of Rochester, Annual Catalogue, 1914–1915. Rochester, no date. (From the University.)
University of Western Australia, Calendar, 1915. Perth, 1914. (From the University.)
Vanderbilt University, Bulletin. Nashville, 1915. (From the University.)
Western Electric Company, Electrical Supply Year Book. New York, 1915. (From the Company.)
Winslow Safety High Pressure Boiler Company, Catalogue of Boilers. Chicago, no date. (From the Company.)

BOOK NOTICES.

LEAVENING AGENTS: Yeast, Leaven, Salt-rising, Fermentation, Baking Powder, Aërated Bread, Milk Powder. By Richard N. Hart, B.S. Easton, Pa., The Chemical Publishing Company, 1914. 78 pages and index, illustrations, 8vo. Price, $1.

This book contains a large amount of information, and will be especially useful to commercial analysts on account of material drawn from trade journals and other sources not ordinarily available in the laboratory. The principal topics are Yeast, Baking Powder, Aërated Bread, and Milk Powder, the latter being somewhat out of the scope of the book, but of value. Interesting information—obtained, the author states, from a private communication—is given as to the manufacture of compressed yeast. A good deal of historical detail is furnished under each of the topics.

The work is numerously illustrated, but many of the cuts are quite inferior. With the modern facilities for obtaining illustrations much better work could have been done with little extra expense. For the sake of some

of the illustrations a heavy and moderately surfaced paper has been used which interferes with good press-work for the general text.

Of the literary style and mechanical execution less praise can be given than for the matter of the book. Typographic errors are not infrequent, sentence-forms are often involved, and common errors in grammar can be found. On page 48 "sauerteig" and "sauertig" occur in adjacent lines, in neither of which, by the way, is the word translated. On page 49 occurs the expression, "Is the salt-rising bacteria a single variety?" a sentence that contains almost as many errors as words. It means, of course, "Are the bacteria of salt-rising dough of one species?" The elaborate reaction-equations on page 52 are in some confusion, are of no use to the trained chemist, and unintelligible to the ordinary practical worker. On page 64 the analyst is directed to take one "grain" of baking powder for a certain test. Probably one gramme is meant. The table of composition and leavening power of baking powders (page 59) is incomplete and seems to contain several errors; for instance, the statement that Royal Baking Powder, analyzed in 1889, yielded only 15.3 cubic inches of gas per ounce of powder. Moreover, the table should state whether this is avoirdupois or troy ounce.

The practical value of this work to the food-chemist will ensure a wide sale; when the second edition is demanded, the author and printer should give more attention to literary form and typographic accuracy.

HENRY LEFFMANN.

EXAMINATION OF WATER FOR SANITARY AND TECHNIC PURPOSES. By Henry Leffmann, A.M., M.D., Ph.D. Seventh Edition, Revised and Enlarged, with Illustrations. 140 pages. Philadelphia, P. Blakiston's Son & Company, 1915. 12mo. Price, $1.25.

The present edition has been extensively revised and the procedures have been brought into general agreement with those recommended by the American Public Health Association. Additional new matter includes summaries of some of the later researches on corrosion of metals by water and details of methods of determining color turbidity and hardness. R.

PUBLICATIONS RECEIVED.

The Chemistry of Cyanogen Compounds and their Manufacture and Estimation, by Herbert E. Williams. 423 pages, 8vo. Philadelphia, P. Blakiston's Son & Company, 1915. Price, $3.50.

Theory of Measurements: A Manual for Physics Students, by James S. Stevens, Professor of Physics in the University of Maine. 81 pages, 12mo. New York, D. Van Nostrand Company, 1915. Price, $1.25.

U. S. Geological Survey: Mineral Resources of the United States, calendar year 1913. Part i, Metals; part ii, Non-metals. 2 volumes, 8vo. Washington, Government Printing Office, 1914.

Canada Mines Department, Mines Branch: Economic Minerals, and Mining Industries of Canada. 78 pages, illustrations, map, 8vo. Researches on Cobalt and Cobalt Alloys, conducted at Queens University, Kingston, On-

tario. Part ii, The Physical Properties of the Metal Cobalt, by H. T. Kalmus and C. Harper. 48 pages, illustrations, plates, diagrams, 8vo. Ottawa, Government Printing Bureau, 1914.

North Carolina Geological and Economic Survey: Economic Paper No. 39, Proceedings of the Good Roads Institute held at the University of North Carolina, March 17–19, 1914, under the auspices of the Departments of Civil and Highway Engineering of the University of North Carolina and the North Carolina Geological and Economic Survey. 117 pages, illustrations, 8vo. Raleigh, State Printers, 1914.

U. S. Bureau of Mines: Bulletin 84, Metallurgical Smoke, by Charles H. Fulton. 94 pages, illustrations, plates, 8vo. Miners' Circular 21, What a Miner can do to Prevent Explosions of Gas and of Coal Dust, by George S. Rice. 24 pages, 8vo. Technical Paper 80, Hand Firing Soft Coal under Power-plant Boilers, by Henry Kreisinger. 83 pages, illustrations, 8vo. Washington, Government Printing Office, 1915.

U. S. Bureau of Standards: Scientific Papers No. 243, The Emissivity of Metals and Oxides. III, The Total Emissivity of Platinum and the Relation between Total Emissivity and Resistivity, by Paul D. Foote, Assistant Physicist. (Reprinted from Bulletin of Bureau of Standards, vol. ii.) 6 pages, 8vo. Washington, Government Printing Office, 1915.

Oxford India Paper. ANON. (*Papierfabrikant*, xxii, 605.)—This paper, formerly made only in England, is now made in other countries; it must be as thin as possible, weighing under 30 grammes per square metre, non-transparent, and very resistant to ink penetration. It is made principally from linen rags, a "standard receipt" being 80 per cent. of best bleached white linen, 10 per cent. of best white bleached cotton, 5 per cent. of bleached straw pulp, 2 per cent. of finest white loading (*e.g.*, talc), 3 per cent. of waste. The rags are boiled with 1 to 2 per cent. of soda for 3 hours at 3 atmospheres pressure, washed carefully and bleached with 1 to 2 per cent. of chlorine until snow white. Ultramarine is used for coloring and indanthrene blue, R.S., for tinting. Beating is carried on for 20 to 34 hours in engines of up to 100 kilos. capacity, with sharp blades so as to obtain a short, non-transparent whole stuff. Cone engines have proved very suitable; sand traps must be used on pulping and beating machines. Paper machines of 150 to 170 centimetres width are most satisfactory, running at not more than 40 metres per minute; wire about No. 90. The strainers should be first a rotary strainer, followed by a flat one, having slots 0.4 mm. wide and fitted with an automatic cleaning device. Shaking should be severe and short. Suction should be weak and couchers and presses lightly loaded so that the paper may have a thick handle. Stone rollers should be employed for the wet-press. The paper must be lightly calendered; moist calendering is not used.

CURRENT TOPICS

Ozonization of Air. M. W. FRANKLIN. (*J. Ind. Eng. Chem.*, vi, 850.)—*Ventilation.*—The modern practice of ventilation is concerned only with the absorption of heat produced by the inmates of a room, with removal of the expired moisture, and destruction of the odors of men, animals, and organic substances. Ozone is most useful in those places where perfect ventilation is impossible. It does not simply mask the organic odors, but destroys them. Onions, decayed fish, decomposed meat, etc., treated with ozonized air had a strong smell of ozone, and after treatment with ferrous sulphate solution to remove the ozone, the substances were free from their natural odor. Chemical compounds produced in the decomposition of organic matter, as skatol, and valeric and butyric acids, are destroyed also. No instance of harm to individuals from the use of ozone in proper concentration in air has been recorded; the workers in the London tube railways and those on water-sterilization plants have shown no ill effects. The use of ozone in quantity to sterilize the air of rooms involves irritation to the respiratory tract. Experiments to determine its germicidal action have given inconclusive results. Its usefulness is not due to any beneficial effects on the human economy, but to the fact that it destroys harmful organic emanations in the air.

Odor Destruction.—Disagreeable odors are given off in the manufacture of casein. Experiments with undried commercial casein showed that the odor was destroyed in the presence of ozonized air, and that the least quantity of ozone required was 1.84 milligrammes per litre of air contaminated with the odor from 15 grammes of casein. In experiments with tobacco smoke, it was found that ozone combined only with the volatile components of the smoke, rendering the smoke odorless, tasteless, and non-irritative, but that it did not oxidize the carbon particles. There was, however, a slight diminution in the smoke density when the air was ozonized: equal weights of tobacco were burned and the smoke collected with equal volumes of air and ozonized air, and in the bottle containing the latter mixture a marked clearing was effected in four hours as compared with the other bottle. Pieces of different kinds of cloth were exposed to tobacco smoke until they had a strong odor; they were then treated with ozonized air and were thoroughly deodorized within half an hour.

Food Preservation.—The effect of ozone on egg-albumin was examined, and it was found that considerable coagulation took place and the albumin turned a yellowish-gray color. Eggs were placed in bottles which were exhausted and then filled with ozonized air.

After ten days, all the ozone had disappeared and the bottles were recharged and examined every ten days. After sixty days the eggs ceased to taste fresh; the loss in weight was about 1.5 per cent. In a control series in the absence of ozone the eggs began to turn stale after twenty days, when the loss in weight was 0.5 per cent. The action of the ozone is to lessen the number and activity of the bacteria which penetrate the shell during evaporation under ordinary conditions.

Use of Electric Furnaces in Brass Foundries. H. G. DORSEY. (*Metallurgical and Chem. Engin.*, xii, 644.)—The furnace employed in these tests was of the Helberger type and of 100 kg. capacity. After describing the construction of the furnace and the tests made with it at the Cash Register Works at Dayton, Ohio, the author states that, considered commercially, this furnace is a failure. It shows many disadvantages and very few advantages. As a laboratory furnace, including experimental work in the foundry on new combinations, it possibly is a good type of furnace, provided a suitable crucible can be obtained. Almost any temperature may be reached and easily maintained for any considerable length of time, and if only a few heats were to be made per week the occasional renewing of crucible resistor, plates, etc., would not be troublesome. To prevent contamination of the metals, some other crucible material, however, would be necessary. For 55 heats five different crucibles were used—an average of only 11 heats per crucible. Working on the above basis no more than 11 or 12 heats could be melted per day, unless the furnace were operated at night, which would mean a new crucible every day. Unless an air blast were used to cool it, the furnace would scarcely get cool enough during the night to insert the crucible the next morning. Assuming ideal conditions, it would require about 31 kilowatt-hours per hundredweight to melt the metal, while the above tests show about 62 kilowatt-hours per hundredweight. Another disadvantage of the furnace is the fact that the crucible is long and narrow, and it is difficult to charge the metal in any quantity, unless the furnace-tender stay beside it and put the metal in piece by piece. This would mean that it would require one tender for each furnace, which would be rather expensive. In a more convenient form the crucible would be a short cylinder of large diameter, but electrically this would be bad, as it would necessitate greater currents. These tests seemed to eliminate the Helberger furnace as a competitor with pit-fires. Other types of furnaces are being tried, but no conclusions have yet been reached. In the discussion Gillett said that this paper gave the first account of commercial work with the electric furnace in a brass foundry. Because the Helberger furnace did not succeed under the conditions of the work at Dayton, it does not follow that all electric furnaces are inefficient. He also pointed out that in considering electric-furnace operations the energy needed to heat the furnace before the work is begun must be taken into consideration.

Relation between Brinell Ball Tests and Scleroscope Readings. J. J. THOMAS. (*Amer. Soc. Testing Materials*, 1914.)—Brinell and scleroscope readings were both taken on each of a large number of metals and alloys, and the results plotted with a view to obtaining a conversion factor. The Brinell tests were made with an "Alpha" machine, having a steel ball 10 mm. in diameter, with a pressure of 3000 kilos. for 30 seconds, and the scleroscope readings were taken with a Shore instrument having a diamond-tipped hammer. The factor for converting the scleroscope readings into the Brinell hardness number is 6.67 for steel, 5.25 for cast iron and bronzes, about 6 for aluminum, and 7.7 for nickel steels. Metals with a Brinell hardness number above 300, or scleroscope number above 45, were found difficult to machine. Tempered steels gave Brinell numbers from 150 to 300. The scleroscope readings varied more than the ball tests on a given sample, due probably to the very small area actually tested by the scleroscope.

Progress in Chemical Pulp Industry. A. KLEIN. (*Papierfabrikant*, xxii, 601.)—The majority of the materials used for paper making in Germany are derived from wood and straw, only about 5 per cent. of rags being employed. In Europe fir, pine, spruce, and large woods are principally used, together with some poplar and beech. Formerly the losses amounted to 20 per cent. from peeling and boring out branches, with 15 per cent. due to sawing into discs, 3 cm. thick; these losses are now reduced to 5 to 6 per cent. by hand peeling and 10 to 12 per cent. by mechanical peeling. Formerly only 22 to 35 per cent. yields of pulp were obtained; the sulphite process now yields 45 to 48 per cent., the sulphate process 35 to 38 per cent., and the soda process 30 to 38 per cent. By increasing the pressure in the digesters the time required in the sulphite process has been reduced from about 36 to 48 hours to 9 to 10 hours, while the use of mechanical stamps to ram the material in the digesters has increased the capacity to 85 to 95 kilos. per cubic metre. Vertical digesters have replaced the earlier horizontal type with improvement in speed of filling. Sulphite liquors containing large amounts of free acid are employed, and the incidental sulphuric acid is reduced by thorough cooling of the gases and absorption surfaces. The injurious effect of selenium in the pyrites used is almost wholly avoided by preventing the formation of dust in roasting. Mechanical pyrites roasting furnaces are employed, and rotary instead of stationary sulphur furnaces. The tower system of liquor preparation is now used more frequently than the tank system. By the recovery of waste gases and by reducing losses of gas and fibre the consumption of sulphur has been decreased considerably; formerly 100 kilos. of unbleached pulp required 45 to 90 kilos. of pyrites or 18 to 20 kilos. of sulphur; at the present time 25 to 26 kilos. of pyrites or 10 to 11 kilos. of sulphur suffice.

The older soda process using 5 to 5½ per cent. caustic soda solutions has been largely displaced by the sulphate process. This process

uses liquors such as the following: 1.5 per cent. Na_2CO_3, 6.2 per cent. NaOH, 2.2 per cent. Na_2S, 0.3 per cent. Na_2SO_3, pressures up to 8 atmospheres being employed. The introduction of improved machinery and processes has led to the recovery of up to 90 per cent. of the soda instead of 58 per cent. as in former times. Of the numerous proposals for the utilization of waste liquors for the manufacture of, *e.g.*, tanning materials, fertilizers, feeding stuffs, dyes, alcohol, etc., the author states that none has given practical results; the most promising are the processes devised for alcohol production. Strehlenert's process seems to be practicable; in this the sulphite liquor yields alcohol, plaster of Paris, sulphur dioxide, and a fuel with a calorific value of 7000 calories. By Rinmann's process 500 kilos. of "carbon," 100 kilos. of spirit and acetone, and 100 kilos. of motor spirit are said to be recovered per ton of cellulose.

Bleaching of pulp is carried out by means of hypochlorites or by electrolytic chlorine. Formerly 100 kilos. of pulp required 30 to 35 kilos. of bleaching powder; 10 per cent. or less now suffices, with a loss of only 4 to 9 per cent. of fibre. Attention is called to the possibility of utilizing such materials as broom rice, flax straw, bamboo, savannah grass, maize stalks, etc.

The Artificial Color Industry and its Position in England. F. M. PERKIN. (*J. Soc. Dyers and Col.*, 1914, xxx, 339.)—After a brief review of the history of the coal-tar color industry, the causes which led or contributed to the decline of the industry in England are summarized thus: The exploitation of the work of English chemists in Germany owing to the imperfect British patent laws and the lack of patent laws in Germany during the earlier stages of the industry; slackness on the part of the early British manufacturers, after a certain period of prosperity; industrial chemical research carried out in Germany but neglected in England; German business organization; restrictions on the use of alcohol. The steps being taken to establish the industry on a large scale in England suggest that the firms now manufacturing colors should enlarge their output and obtain leave to work certain German patents; that many of the raw and intermediate products, such as benzene naphthalene, anthracene, and their derivatives, should be manufactured at one or two of the great gas works, and that a few new companies should be started, preferably with capital furnished, at least in part, by color users. In an industry such as that of the artificial colors a number of highly-trained research chemists must be employed, as success will rest with the works capable of turning out the largest number of new colors and at the same time improving the methods of manufacture and the quality of the older ones and devising means of profitably utilizing by-products. In this connection it is pointed out that the great profits made in the earlier stages of the industry by German firms were employed in the first case to write off capital expenditure, and, secondly, to reconstruct their works and provide well-equipped laboratories

staffed with skilled research chemists. The restrictions on the use of alcohol have been considerably mitigated, largely owing to the efforts of T. Tyrer, but it is stated that there is room for considerable improvement in the administration of the government acts. The use of pure alcohol is of even greater importance in the manufacture of drugs and photographic chemicals—an industry almost entirely in German hands before the war—than in the color industry.

New Building of the Mellon Institute.—The new building which will form the permanent home of the Mellon Institute of Industrial Research and School of Specific Industries of the University of Pittsburgh was formally dedicated on February 26. The building is the gift of Messrs. Andrew William and Richard Beatty Mellon, of Pittsburgh, and was especially designed for the needs of the Institute. It is distinctly modern in every respect, and complete facilities are provided for the investigation of manufacturing problems and for conducting industrial research.

The new home of the Mellon Institute is a five-story-and-attic building. The basement contains seven rooms: the main storeroom, the boiler room, the electric furnace room, a heavy apparatus room, a room equipped for low-temperature work, the machine shop, and the kitchen. On the first floor are located the general offices, the library, the assembly hall, a special apparatus room, and a dark-room laboratory. The second and third floors each contains ten large research laboratories and nine small ones; the fourth floor, which is not finished, will contain an identical number of laboratories so soon as the growth of the Institute warrants its completion.

While the Mellon Institute possesses an endowment of its own and has its own Board of Trustees, it is an integral part of the University of Pittsburgh. The dedicatory ceremonies were accordingly held in conjunction with the annual Charter Day exercises of the University.

Tests of Automobiles at the Royal Technical University, Charlottenburg. A. RIEDLER. (*Engineering*, xcviii, 109.)—In these tests the car was placed on a test-bed with its wheels resting on rollers, the shafts of which were connected to two friction brakes and also to dynamos capable of being used as motors. The power can thus be measured either by the dynamos or by the brakes, so that the various items of both power and loss can be measured separately as nearly as possible under actual running conditions; *e.g.*, the motor is tested, mounted on the chassis. Tests are given of a 30-horse-power Rénault touring car, a 100-horse-power Benz racing car, a 70-horse-power Adler touring car, a Mercédès electromobile, a 35-horse-power Büssing military transport wagon, a 40-horse-power English Daimler-Knight car, and a Mercédès-Knight-engine; comparative tests were also made between the Knight and poppet-valve systems. In the tests the following points were apparent, viz.: a large increase of

power is obtainable by the use of large valves; the loss of power between the engine and the back wheel rises with the engine speed; although the top speed is direct in all four cars tested, the loss by gearing does not seem to increase materially on the lower speeds; the loss through rolling resistance of the wheels (21 per cent.) is greater than that through friction in transmission (12.7 per cent.), the loss in the back wheels (16.2 per cent.) being far greater than that in the front (4.8 per cent.): the figures are given for a Rénault car running at 37½ miles per hour. On the lower speeds, when the driving stress is very high, the rolling resistance is found to be sometimes as much as ten times that of the same wheels running light. The efficiency of the transmission gear of the English Daimler with worm-drive is given as varying from a minimum of 84 per cent. on the lowest speed to a maximum of 90 per cent. on the top.

New Paths of Physical Knowledge. M. PLANKS. (*Phil. Mag.*, xxviii, 60.)—The fundamental changes in the main structure of physical theories are essentially constructive—not destructive—leading to modification and amplification of existing theory by the old way—conflict between experimental fact and portions of hitherto accepted theory. Now as before, the great physical principles still hold the field; *e.g.*, the conservation of energy, the conservation of momentum, least action, the chief laws of thermodynamics. But assumptions hitherto accepted almost without question are proving untenable, or at any rate doubtful; *e.g.*, the invariability of chemical atoms, the mutual independence of space and time, and the continuity of all dynamical effects. The fact of heat evolution by radium compounds placed the first in conflict with the conservation of energy, and the principle holds the field. If relativity be assumed to be experimentally established, the mutual independence of space and time comes into conflict with the so-called principle of the constancy of the velocity of light established by the electrodynamics of Maxwell and Lorentz. The latter has so far held the field, and it is not at all probable that any abandonment of that position will occur. The assumption of the continuity of all dynamical effects had long been accepted as a basis for all physical theories, but is now found in direct conflict with the experimental facts which have given rise to the quantum hypothesis. The disintegration of the energy of motion of water waves by continuous diminution of amplitude does not proceed indefinitely, but finds a certain limit in the size of the atoms. The atoms hold the energy together in a way, each atom representing a certain finite material quantum which can move only as a whole, and the larger the atoms the less can the total energy of motion be subdivided. This is quite in accordance with classical theory, but according to this the disintegration should proceed without limit in the case of the repeated reflection of light waves within a hollow enclosure—the infrared and visible rays should gradually disappear and become converted ultimately into invisible ultraviolet or chemical rays. But of such a

phenomenon no trace is discoverable in Nature. The conversion here also attains, sooner or later, a perfectly definite and assignable limit, and after that the radiation conditions remain stable in every respect. The old theory proved untenable, but the principles of thermodynamics have shown themselves to be unshakable. The only solution of the riddle appears to be that, even in the case of the immaterial light and heat rays, certain processes must be at work which hold together the energy of radiation in definite finite quanta, and unite it the more strongly the shorter the waves, and the greater, therefore, the oscillation frequency. In what way we are to conceive the nature of merely dynamical quanta we cannot yet say for certain, but the hypothesis has certainly led to the idea that there are changes in Nature which occur, not continuously, but explosively. Moreover, the quantum hypothesis affords solutions of still more recent discoveries which are in conflict with the classical theory; *e.g.*, of the observed fact that to raise a piece of copper through one degree at 250° C. requires only about one-thirtieth of the heat required to raise it through one degree at 0° C., and that if we took the original temperature of the copper still lower, the corresponding quantity of heat would turn out many times smaller, without any assignable limit. The quantum hypothesis has also led to the most important result that the forces controlling the thermal oscillations in a solid are of the same kind as those which control its elastic oscillations, enabling us to calculate the thermal energy of a monatomic substance at various temperatures from its elastic properties, a performance far beyond the reach of the classical theory. Puzzling though the nature of dynamical quanta may be, it is difficult to doubt their existence, in some form or other; for whatever we can measure must exist.

Camphor Production in India. (*Chamber of Commerce J.*, December, 1914.)—The camphor tree (*Cinnamomum camphora*) has been successfully planted in Burma, Ceylon, and the Federated Malay States. In Burma there are plantations in the upper Chindwin, Myitkyina, Bhamo, and southern Shan States. There are experimental plantations in the Nilghiri Hills and in certain isolated patches of Bombay and Madras. In Ceylon the tree grows only in the more elevated parts: there is a plantation at Hakyala. Great difficulty has always been experienced in getting good seed imported direct from Japan, and there is often wholesale failure to germinate. The seeds sown for the Burma plantations were obtained from Hong Kong. Camphor is obtained also from an evergreen shrub (*Blumea balsamifera*) which is indigenous to the Shan States of Burma. It also grows in the islands of Hainan and Formosa and in South China.

Telegraphy with Alternating Currents. (British Patent 18,321 of 1913; *Elect. Engineering*, x, p. 487.)—The patent refers to a system of telegraphy in which alternating or interrupted current can be used for ordinary telegraphic signalling, and is stated to be particu-

larly applicable to ocean cables. An alternator is used for transmitting purposes; one pole is earthed, the other being connected through a signalling key, condenser, and sensitive relay to the line circuit. The apparatus is the same at each end of the line, the sensitive relay controlling a sluggish relay, which in turn controls a sounder. Thus firm Morse signals appear on the sounder. It is stated that when alternating current is used for signalling the capacity and resistance of the cable do not interfere with the speed of working, as in the case of direct-current systems.

A New Reagent for Etching Mild Steel. W. ROSENHAIN and J. L. HAUGHTON. (*Iron and Steel Inst. Journ.*, lxxxix, 515.)—To obtain satisfactory results the following formula must be followed with considerable exactness: Ferric chloride 30 gm., concentrated hydrochloric acid 100 c.c., cupric chloride 1 gm., stannous chloride 0.5 gm., water 1 litre. In pure carbon steels the resulting pattern is the reverse of that produced by picric acid, but the most important property of the new reagent lies in the fact that it reveals in an unmistakable manner the distribution of phosphorus in mild steels, yielding results which are comparable with those obtained by heat-tinting. The cause of the pattern is the deposition of very thin films of copper. In unhardened steels ferrite is colored black, while in hardened steels martensite is developed in a remarkably clear manner. In commercial steels patterns identical with those obtained by heat-tinting are produced. The new reagent is extremely sensitive to the presence of phosphorus, the ferrite containing the least amount of phosphorus in solution being darkened first. It is therefore much more sensitive than picric acid in revealing the presence of ghosts. It appears that the width and distribution of the phosphorus banding depend upon the size and arrangement of the crystals in the original ingot. There is always considerable darkening round the enclosures of slag and sulphides in steel, which appears to indicate that there is a concentration of dissolved impurities in the immediate vicinity of such enclosures.

Stress Distribution in Engineering Materials. (*Engineering*, xcviii, 315.)—The object is to collect complete and systematic data on the stress distribution in a dead, mild steel containing 0.12 per cent. carbon, an axle steel containing 0.3 per cent. carbon, and a nickel steel. In a preliminary report Rogers gives an outline of the method of manufacture of the dead, mild steel, and Filon and Coker summarize the methods which have been proposed and used for the determination of the distribution of stress and strain in solids.

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